The INSTITUTION *of* PRODUCTION ENGINEERS

JOURNAL

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CONTENTS

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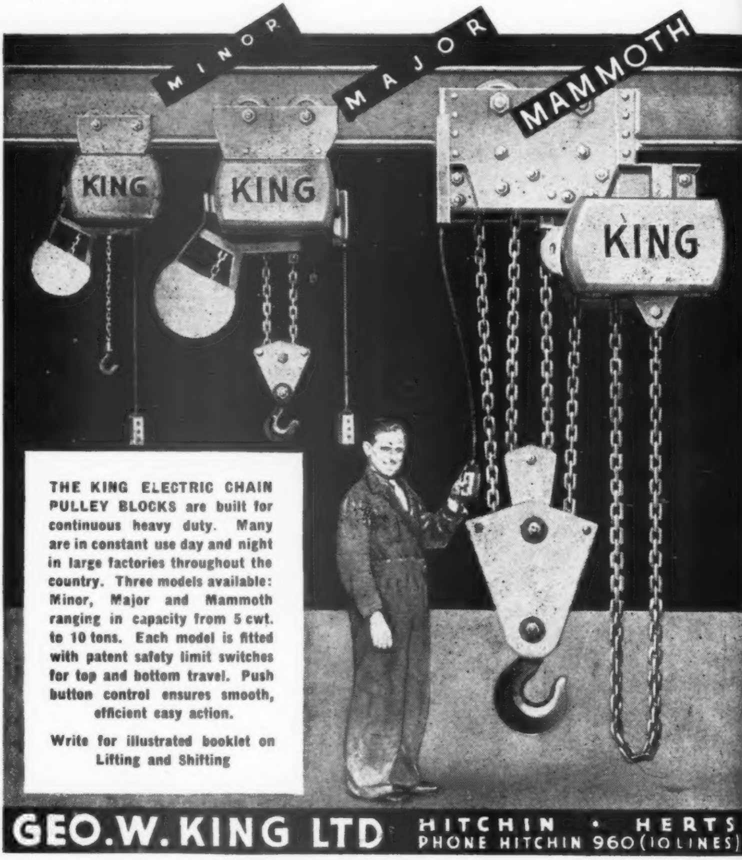
KING *Electric* CHAIN PULLEY BLOCK



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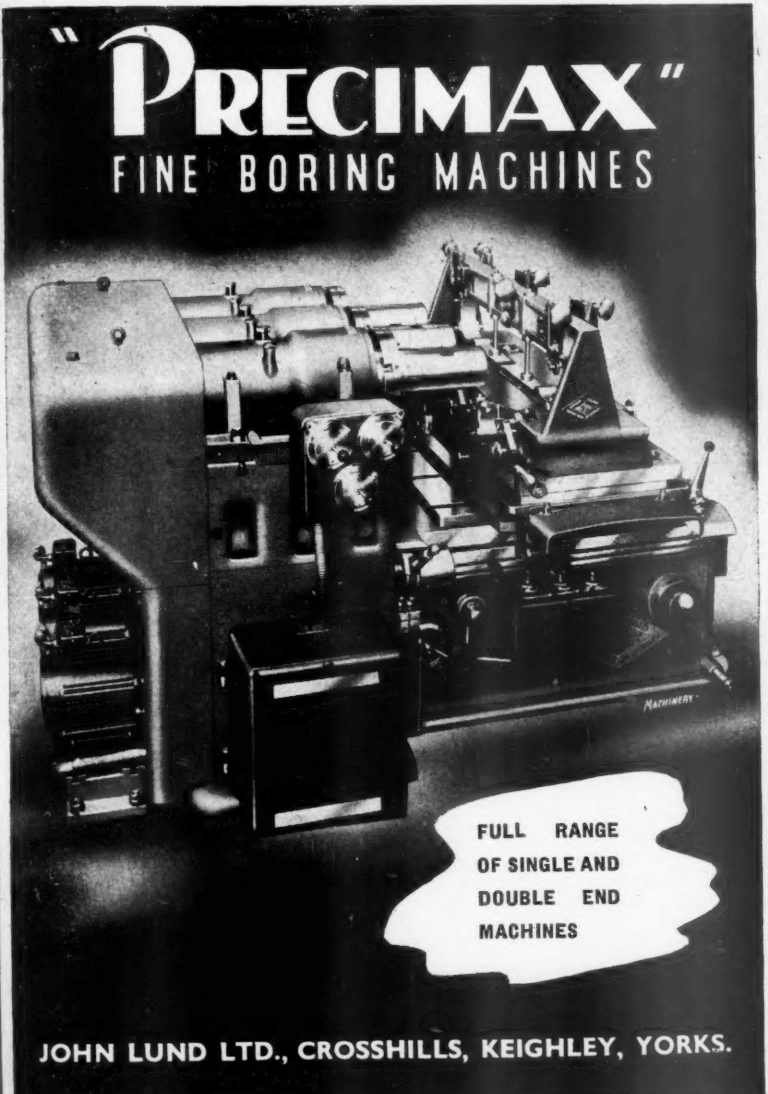
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INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*

The fact that goods made of raw materials in short supply owing to war conditions are advertised in " The Journal " should not be taken as an indication that they are necessarily available for export.

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1943-44

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INSTITUTION NOTES

June 1944

July Meeting.

25th Wolverhampton Section. Meeting at the Technical College, Dudley, at 6-30 p.m., when Dr. K. G. Fenelon, will lecture on "Foremanship."

June Committee Meetings.

23rd Council meets at the Institution of Civil Engineers, London, at 11-30 a.m.

July Committee Meetings.

4th Education Committee at the Queens Hotel, Birmingham, at 10-0 a.m.

4th Membership Committee at the Queens Hotel, Birmingham, at 12-30 p.m.

16th Research Finance Committee at the Black Boy Hotel, Nottingham at 5-0 p.m.

16th Research Management Committee at the Black Boy Hotel, Nottingham, at 6-0 p.m.

17th Research Management Committee at Loughborough, at 10-0 a.m.

21st Finance and General Purposes Committee at Institution Headquarters, at 1-0 p.m.

The Technical and Publications Committee meet at Institution Headquarters every Wednesday at 5-30 p.m.

Honours List.

It is with much pleasure that we record the honour conferred on two of our members by His Majesty the King. Mr. E. J. H. Jones, of the Associated Equipment Co. Ltd., and Mr. F. T. Nurrish, of Geo. Bray & Co. Ltd., have been awarded the M.B.E. for their services to the national production programme.

Personal Column.

The many friends of Mr. T. Fraser will be pleased to learn that he has been elected to the board of directors of the Metropolitan-Vickers Electrical Co. Ltd. Mr. Fraser is a past Chairman of Council and has also been President of the Manchester Section.

Mr. H. D. S. Burgess has recently been appointed planning engineer to The Humber Co. Mr. Burgess is a past President of the Coventry Section and prior to his Coventry associations was an active member of the Luton and Bedford Section. He is a member of Council and serves on a number of the Institution Committees.

Research Department Appeal.

The Council of the Institution gratefully acknowledge the undermentioned contributions to the Research Department which have been received during the current financial year.

Many of these contributions have been in response to the recent appeal made by our President, Sir Ernest Lemon, O.B.E., and the Council wish to express their sincere appreciation to all those who have so readily and generously responded.

Contributions Received by the Research Department.

	£	s.	d.
Jones & Shipman, Ltd.	100	0	0
Frank Guylee & Sons, Ltd.	10	10	0
Associated Equipment Co., Ltd.	100	0	0
Weir Precision Engineering Ltd.	50	0	0
Machine Tool Trade Association	1050	0	0
J. Kerr, Esq.	5	0	0
N. Davis, Esq.	0	10	6
E. Pryor & Sons	20	0	0
Metropolitan-Vickers Electrical Co. Ltd.	100	0	0
The Gramophone Co. Ltd.	100	0	0
I. L. Berridge & Co. Ltd.	10	0	0
Gent & Co. Ltd.	20	0	0
E. P. Jenks, Ltd.	10	10	0
Owen & Dyson, Ltd.	10	10	0
Yale & Towne Manufacturing Co.	10	10	0
The Diamond Trading Co. Ltd.	50	0	0
Charles Richards & Sons, Ltd.	2	2	0
George Kent, Ltd.	25	0	0
Thomas White & Sons, Ltd.	25	0	0
Ceandes, Ltd.	5	5	0
E. R. & F. Turner, Ltd.	25	0	0
A. P. Newall & Co., Ltd.	26	5	0
Chance Bros. Ltd.	25	0	0
J. Brockhouse & Co. Ltd.	10	0	0
Peglers, Ltd.	21	5	0
Clayton Dewandre, Co., Ltd.	25	0	0
Percival Aircraft, Ltd.	10	10	0
Crane, Ltd.	31	10	0
Myford Engineering Co. Ltd.	5	5	0
E. Barr	1	1	0
The Birmingham Small Arms Ltd.	25	0	0
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Markham & Co., Ltd.	50	0	0
E. Nicklin & Sons	5	5	0

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A. Bailey	3	10	6
B. E. Curran	3	3	0
P. Horbrough	2	10	0

	£	s.	d.	£	s.	d.
Robert Scaife (Wales) Ltd. ...	2	10	0			
C. H. Oakes	2	2	0			
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E. R. Jacobs	2	2	0			
C. L. King	2	2	0			
E. T. Mordecai	2	2	0			
A. W. Homer	2	2	0			
J. Vaughan	2	0	0			
D. H. Milnes	1	11	6			
G. L. Horman	1	1	0			
R. James	1	1	0			
H. Walker	1	1	0			
R. O. Williams	1	1	0			
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W. T. Jones	1	1	0			
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L. G. Mockeradge		10	6			
F. Tilbert		10	6			
T. J. Davies		10	6			
H. T. Jones		10	6			
H. Elkin		10	6			
A. O. Williams		10	6			
R. Mumby		10	6			
R. R. Marriott		10	0			
D. H. Young		10	0			
T. Quinton		10	0			
J. W. Goldingay		10	0			
L. Chubb		10	0			
L. N. Atkins...		10	0			
P. Bullock		10	0			
W. J. Rose		7	6			
C. Jones		5	0			
				44	0	0
E. K. Cole, Ltd.				50	0	0
Ericssons Telephones, Ltd.				50	0	0
Kelvin, Bottomley & Baird				10	10	0
Birmid Industries				26	5	0
Reavell & Co. Ltd.				26	5	0
The Garrard Engineering & Mfg., Co. Ltd.				10	10	0
The Electrical Apparatus Co. Ltd.				5	5	0
Ruston Bucyrus, Ltd.				100	0	0
Hobbies, Ltd.				10	10	0
Sheffield Twist Drill & Steel Co. Ltd.				50	0	0
Total to date (20th June, 1944)				2421	8	0

BOOK REVIEW.

Minerals in Industry, by W. R. Jones. Pelican Book Series, Price 9d.

This book deals with the minerals in general industrial use, giving brief information of their use in industry together with their occurrence and production commercially.

It is a book of great general interest to Production Engineers as the information given sheds light on the reasons governing the application of various minerals to their everyday problems.

Under war-time conditions the use of many minerals is restricted but on the other hand many have increased applications, and are sometimes used when the pressure of war problems causes the cost factor to take second place.

There is much speculation about the effect this will have on the use and availability of minerals when we return to more normal conditions, and the Production Engineer will find the information given in this book very helpful in trying to forecast the probable position, and to free his mind from the opinions so freely expressed on these matters by marketing publicity.

R.E.L.

CAR PLANNING PRINCIPLES AS APPLIED TO AIRFRAME PRODUCTION

Paper presented to the Institution, Coventry Graduate Section, on 1st November, 1943, by B.G.L. Jackman, Grad.I.P.E.

THIS paper is based on first-hand experience of working in a planning capacity on sub-contracts of major airframe components for various aircraft manufacturers. Criticisms of the design of details will appear from time to time during the course of this paper, but at the outset I would make it clear that the reason for unsatisfactory production design is easy to find—it is the natural

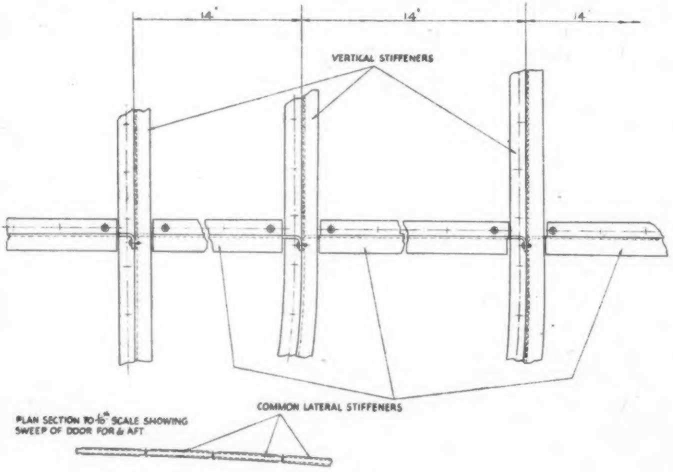


Fig. 1

evolution of limited quantity production, when prior to this war an order for 12 or 20 machines of a type was an outstanding event and well worth recording in the annals of the company with whom the order was placed. Small quantities of aircraft were, almost without exception, built up by hand by skilled personnel, and such tools as were made (if indeed you could call them tools) were made by indi-

vidual operators as part of the process of making the 12 or 20 sets of any particular detail.

Recent trends by the Government, however, through the Ministry of Aircraft Production, have made the contract quantities of sufficient size to merit good and accurate tooling right from the outset; it is seldom that quantities less than several hundred plus spares are now ordered even on initial contracts for a new type of aircraft. It is this factor which facilitates the application of the quantity production methods of pre-war car manufacture to aircraft construction.

First of all you will ask, very naturally, "What are car planning principles?" Right away I would say that they are principles which are *not* actually peculiar to car production, but which exist in most

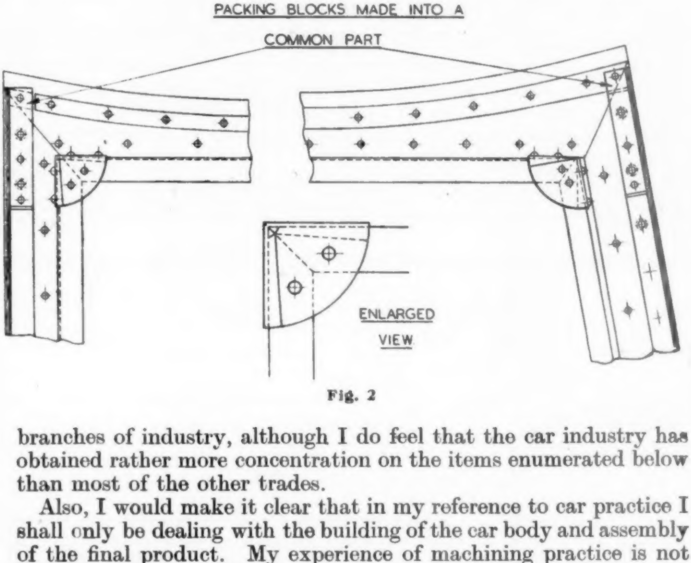


Fig. 2

branches of industry, although I do feel that the car industry has obtained rather more concentration on the items enumerated below than most of the other trades.

Also, I would make it clear that in my reference to car practice I shall only be dealing with the building of the car body and assembly of the final product. My experience of machining practice is not great, but it is apparent that machining practice is largely common ground irrespective of product and that aero engine production methods do not in the main differ largely from automobile engine production. In the same manner you will appreciate that there is a certain amount of kinship between the labour, tools and production methods used on airframe work and on car body and assembly work, as they are both basically press and sheet metal work of various forms. So, out of the large variety of habits and practices which exist in car production of recent years, I have chosen the

following major points which I feel can be termed principles; they are listed in the order of their importance.

1. Simplification of design and standardisation wherever possible.
2. Accurate component drawings.
3. Accurate, robust and plentiful tooling.
4. Line production.
5. Time study.

It is proposed to deal with all these headings in turn, giving the reasons for choosing these items and explaining how we set about obtaining the best results during which I hope to quote examples which will help to drive home the accuracy of my assertions.

1. Simplification of Design and Standardisation.

Everyone present is fully conversant with the existing war-time pressure of events and the need for rapid production from zero. Unfortunately this pressure tends to make a planning engineer or planning department on any particular contract inclined to take the line of least resistance and carry on planning and tooling exactly

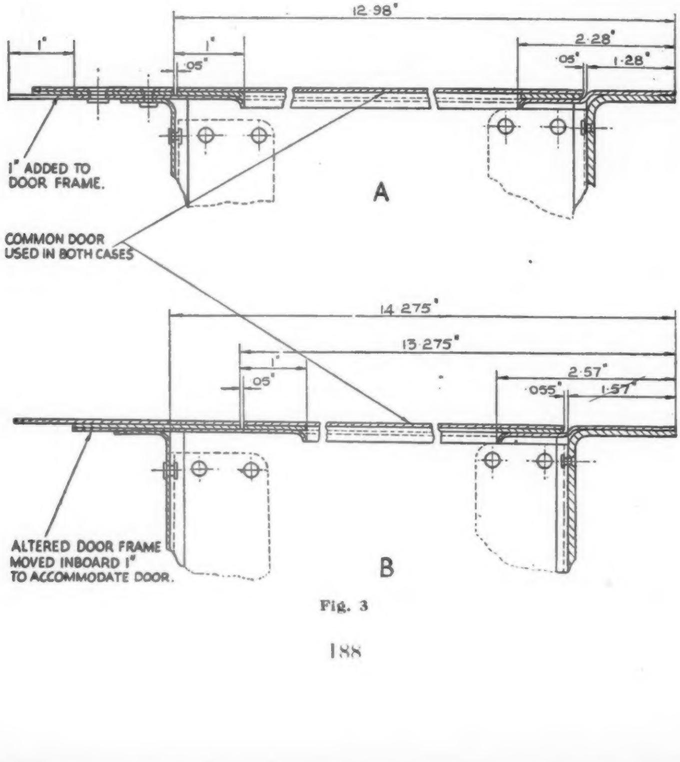


Fig. 3

in line with the drawings received from the design department or, in the case of a sub-contractor, from his parent or main contractor.

It would appear on the face of things that the time which would be saved by not querying drawings or altering them slightly to facilitate manufacture (followed naturally by submission to design for approval) would result in the saving of planning personnel and available man hours, but this is a complete fallacy.

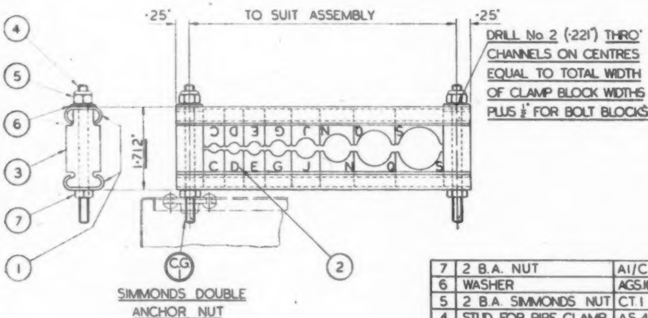
Just pause for a moment and weigh up the alternatives. On the credit side you have possibly up to some 20 to 30 man hours saved per component in the initial planning stage ; on the debit side you

Fig. 4

have greater difficulty on assembly planning, greater difficulty on tool planning, extra man hours to effect additional or more complicated tools, and the production of two or three slightly different components, when one common one could suffice. It simply is not sufficient to plan and produce the job as it is presented through the medium of drawings from design department. One must always be on the alert for means of reducing the number of parts, effecting slight alterations to design to facilitate production on existing equipment and in general seizing every opportunity for standardisation in any direction.

Very briefly one must plan economically, a factor which was always kept in front of the planning department on car production, mainly because a commercial firm can only allow a planning department to spend an amount of money annually on plant and equipment for improving efficiency and increasing production which it could be proved in black and white would be saved on the year's working. In car production one essentially works from year to year, owing to the changing models, and it is not possible to allow the recovery of expenditure to spread over more than the current year's working except in very special cases.

With regard to airframe production one of the greatest aids to simplification of design and a reduction in the number of different component parts is to have available a complete full-size layout similar to the practice on car body design. The contours and double curved surfaces on most airframe units provide an ideal field for layout and the necessary projections for amplifying tool drawings and facilitating tool manufacture. A description of procedure in this direction will be discussed later in the paper, as these layouts are also necessary for checking purposes, but it is so easy with layouts available to take a tracing off one component and lay it against or on, another unit, showing up immediately any difference in contour and overall dimensions without having to cross check



REF	DESCRIPTION	PART No
7	2 B.A. NUT	A1/CT
6	WASHER	AGS.160/C
5	2 B.A. SIMMONDS NUT	CT.1
4	STUD FOR PIPE CLAMP	AS 450
3	BOLT BLOCK	AS 448
2	PIPE CLAMP BLOCKS	AS REQ^{D}
1	STRIP (LENGTH AS REQ^{D})	AS 449

Fig. 5

all the figures shown on the different drawings. To illustrate my points I have here a few typical examples chosen from among many others, showing the various stages to which standardisation or simplification can be carried.

From a practical point of view the illustrations already given may be examined. Fig. 1, for example, shows some sections of a drawing of a typical side door from the nacelle fairing of an aircraft. The door itself was curved in two planes, one curve following the sweep back of the nacelle and the other curve in a vertical plane to blend into the undercarriage door. The door had lateral stiffeners along the approximate centre line, all of which were different lengths and different component numbers, although made basically from the same raw material section. From our full-size layout, we

find that the curve was constant for the last three out of four of the lateral stiffeners, and that in effect they could be the same part, except that the lengths varied by small amounts up to $\frac{1}{4}$ in. It was suggested and agreed that the vertical stiffeners should be moved accordingly to give a constant length to these last three lateral stiffeners, thus making a common part and avoiding the duplication of drilling jigs.

In Fig. 2, we also suggested that the corner packing pieces, which were of a different length and with a different number of holes, could be standardised as a common part. This means achieving a mean bevel on one end of the strip, thus making it suitable for use on both sides of the door. Another point where we saved tools was to make the corner plates from a common blank and first operation raising tools, leaving the final operation on each part as a setting to the appropriate angle required.

Fig. 3, shows two access orifices in the fuel tank doors, providing entry to the filler cock in two different sizes of tank. The structure of the doors was such that the stiffeners adjacent to the access door were different distances apart and the original access door design went from stiffener to stiffener in each case. To retain the use of a common door, we increased the width of the door frame section by 1 in. inwards on one of the doors, as shown. This avoided the use of a different size door with naturally a different kit of tools.

N.B.—All these suggestions were immediately agreed by the design department.

Fig. 4, is a photograph of a typical pipe cleat which was in existence at the beginning of the war, made up of a large quantity of pieces of spruce and plywood glued together. Each cleat had to be made to different dimensions for each and every batch of pipes, and in most cases was fastened to the airframe structure by different forms of mounting brackets. The electrical bonding of the pipes was achieved by copper foil clamped against the pipes and connected by copper braid to the structure of the machine. Fortunately this type of special cleat has now been largely superseded by a standard form of cleat drawn up by the S.B.A.C. Standards Committee, which is illustrated in Fig. 5. Most people are familiar with the excellent work of the S.B.A.C. Standards Committee, covering as they already have a vast amount of equipment, ranging from rivets to pilot's seats and control columns, but I do feel that a very great deal more could be achieved in this direction, if designers went out of their way to standardise on such things as extruded stringer sections and standard access doors, to mention only two examples. I do not feel it is necessary to have such a wide range of rolled and extruded section material, differing as they do from one another by such

small amounts as .050 in., and it is apparent in most cases that designers have not bothered to check and cater for the use of existing forms of section, which in all probability are already in use in their own organisations.

I hope that these few examples out of a great many will serve to illustrate the point I desire to make, which is to simplify and standardise wherever possible.

And bearing this question of standardisation in mind, as it has a bearing on it, we come to our next main principle.

2. Accurate Component Drawings.

One of the most important necessities before tooling can commence is that the component drawing shall be accurate and dimensionally correct. No doubt to some machine tool and engine production experts this seems rather an unnecessary assertion, but with aircraft design it needs a great deal of emphasis.

The general practice with aircraft design, owing to the large size of the article to be produced is to draw almost everything to quarter-scale, and immediately the accuracy of drawing is limited. As so much component design is concerned with curves in two planes, projections are necessary for determining intersection and boundary lines. Consequently slight errors of a few thousandths of an inch (and few draughtsmen can attain greater accuracy than .010 in. —the thickness of a fairly thin pencil line) are magnified several times with the result that the final component may be .020 in. or .030 in. out while still in quarter-scale form and while being dimensioned up in line with the physical drawing. On conversion to full-size tool information, errors of from $^1/_{16}$ in. to $\frac{1}{4}$ in. begin to creep in, with the result that the parts will never go together satisfactorily.

To overcome this trouble the standard practice for all new and unproved products is to re-layout the whole machine or section to be constructed on large draughting boards of a size suitable for taking the various assemblies. We use boards 16 in. × 8 in. almost vertical, covered with 16SWG light alloy sheet and painted with a special paint, slightly off-white to reduce glare and the consequent tiring of draughtsmen's eyes. Naturally the boards may be horizontal if preferred, although this means climbing and laying over work already done to effect some additions. In the United States it is usual to have a " Lofting Room " in which the whole floor is one gigantic drawing board capable of taking the outline and details of the complete aircraft in full size. We prefer the vertical boards, as it is a practice to which our draughtsmen are more accustomed ; these boards are in most cases large enough to take most single units of a modern aircraft. The boards and practice are well-known to car-body designers and manufacturers,

but I will elaborate a little for the benefit of those who are associated with different trades or professions.

The boards are covered laterally and vertically with datum lines 10 in. apart, from which all measurements are based, thus eliminat-

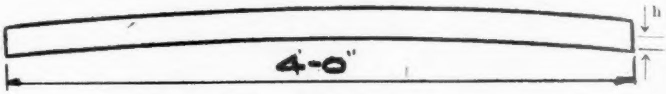


CHART FOR BODY SWEEPS—Length of Sweep 4 feet

No. of Sweep	Actual Rad. in Inches	Rad. To Nearest ¼ in.	No. of Sweep	Actual Rad. in Inches	Rad. To Nearest ¼ in.
1	2304.0625	2304	27	87.0208	87
2	1152.125	1152	28	84.0557	84
3	768.1875	768¼	29	81.2608	81¼
4	576.250	576¼	30	78.675	78¾
5	461.1125	461	31	76.2600	76¼
6	384.375	384½	32	74.0000	74
7	329.5804	329½	33	71.8806	72
8	288.500	288½	34	69.8897	70
9	256.5625	256½	35	68.016	68
10	231.025	231	36	66.25	66¼
11	210.142	210	37	64.5827	64½
12	192.750	192¾	38	63.0065	63
13	178.0432	178	39	61.5144	61½
14	165.4464	165½	40	60.100	60
15	154.5357	154½			
16	145.000	145			
17	136.5919	136½			
18	129.125	129			
19	122.4500	122½	2½	921.7562	921¾
20	166.450	166½	3½	658.5044	658½
21	111.027	111	4½	512.2812	512¼
22	106.1022	106	5½	419.2528	419¼
23	101.6114	101½			
24	97.500	97½			
25	93.7225	93¾			
26	90.240	90¼			

Fig. 6

ing the build-up of dimensional errors in progressing from one component to the next. As mentioned previously, the majority of good layout draughtsmen can keep any error (due to slight individual differences in their methods of drawing, i.e. holding pencil, type of pencil, etc.) to about .010 in. which obviously is closer than any sheet metal or large contoured product can be kept in production.

All contoured sections are based on standard curves or sweeps made from steel — usually rising $\frac{1}{8}$ in. in 4 feet length ; exact duplicates of this Drawing Office equipment are available in the toolmaking shops for re-translation of the information on the additional information drawings to the physical tool. Very few contour radii are too small for coming into the range of the standard sweeps—those which are can be evolved using frequent offset dimensions and trammels or even special templates made in the drawing office from thin .010 in. stainless steel.

Fig. 6 is a chart showing the main dimensions of the standard body curves of sweeps which are provided in the drawing office and toolroom for translation of drawing information on to the physical tools. The large advantage of these sweeps over splines is that the curves produced cannot vary between ordinates according to the method of handling by different personnel, as happens with the latter equipment.

From these full-scale layouts, component drawings are re-dimensioned or newly derived giving key projections, sections and all the additional information which are so often necessary to facilitate the toolmakers' work.

Another cause of trouble is the habit of the aircraft designer with minor assemblies to show all the details on the one drawing, called up as various stroke numbers of the main drawing number. This often results in very sketchy and incomplete, as well as inaccurate, information being provided, due to space limitations and almost invariably means that only one view of any component is shown as it lies in position on the assembly. Here again we make detail drawings of components in almost every case taking our data from layout and providing as much additional information as possible, the only exceptions being nuts, washers and other similar standard proprietary parts.

You will no doubt argue that the above represents a colossal load of work taking several months for a major component and that surely it would be quicker to produce to existing drawings, even if they are not perfect, and correct the article later. If you are building one aircraft I would agree with you, but not when tools are being made for quantity production.

I have tried both methods and although initially production may appear to be forthcoming sooner by hand-making first, the layout

and accurate tooling method wins hands down at the end where quantity is involved.

It is admirably illustrated by the rates of production of three different firms on a common product which actually occurred during this war.

Fig. 7 represents the growth of production by three different manufacturing units on a common product, in line with the methods of tooling. Firm 1 produced the first unit by hand to original

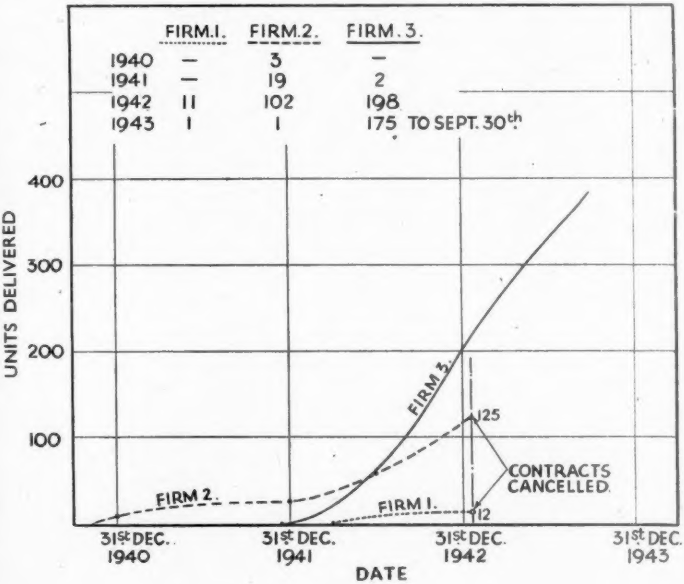


Fig. 7

drawings and made parts and tools from the first one. This, in effect, was the old method adopted by most aircraft manufacturers in this country until three or four years ago. Firm 2 produced tools to existing component drawings and produced from those tools with the consequent alterations to both production and tooling when it was found that parts simply would not go together satisfactorily without a very large amount of fitting. Firm 3 carried out a complete full-size layout and made accurate tools, holding back production until all the major tools were completed.

We must be careful in criticising the aircraft industry and its designers for, like a lot of other people, they are colossally overworked with insufficient staff. We must all agree the industry as a whole has done a fine job and kept British aircraft in the forefront in all branches of the industry, fighters, bombers and, we hope, transport. To effect this has meant new types and constant changes and modifications to the old types, all of which has taxed the design and drawing offices to the limit of their capacity. Just when it is felt that more detail and more information could be added to existing drawings, in all probability a new design has been asked of them and so they have had to give just sufficient information and detail on the drawings to enable the aircraft to be built—no more and no less—and while the war lasts I am afraid we production people will have to be content with supplying ourselves, by our own efforts, the additional data we require to make a satisfactory production job. In fact I would go as far as to advocate this policy as obviously there is no one better suited to decide what information he requires adapted to the plant and layout facilities of his own concern than the planning or production engineer, whose job it is to produce the article.

I am strongly in favour of the setting up of production drawing offices in all large concerns to mould the design information into a production form and naturally leaving the design department the right to veto any particular departure from drawing if the resulting product is likely to be effected. It is all very well to say that design people should become production minded and that one drawing office should suffice. I do not feel that this is practicable except at a great loss of initiative and ability in both spheres. There is far too much material and experience in present-day production methods and technique to expect one brain, or one collection of brains to absorb both this and all the highly developed design data and training necessary as well. If this were possible then obviously a large proportion of the need for production engineers and our Institution would vanish—and yet we all know that it is a very great need, and one that is growing daily.

An additional duty which a Production Drawing Office could fulfil would be to prepare the whole range of specialised drawings which are required for the use of present-day unskilled and semi-skilled male and female labour.

These comprise :

(a) Operation drawings—for machined parts.

(b) Perspective drawings of sub-assemblies with suitable broken section views—a fashion which is growing considerably in the training of " green " labour.

(c) Full-size skin panel drawings showing clearly all types of rivets, spot welds, etc.

(d) Application drawings of components to jigs and interchangeability gauges.

To conclude this section I would quote a paragraph from the recent report of the Select Committee on National Expenditure regarding aircraft production, which admirably summarises the issue, although it does not advocate quite the same approach to the problem.

Referring to design and production liaison, the report states: "Efficient large-scale production depends on the design and upon the use of the best production technique. Where necessary design staffs should be strengthened by the appointment of draughtsmen with actual experience of production engineering. The design and development department, the department responsible for planning the methods of production and the workshop should work closely together at every stage, and should be as close to each other as possible. This is not always the case."

3. Accurate Tooling.

Tooling for major airframe component production very briefly falls into three categories.

1. Machined parts.
2. Press work and sheet metal work.
3. Assembly.

While I do not propose to deal in detail with all the various aspects of tooling relative to the various categories of work to be performed, I will briefly run through the main principles and methods which we adopt on present-day aircraft production, showing where possible the effect of car production tooling technique.

With regard to machined parts, tooling is very much the same as with any other industry except that in some cases, owing to the quantities not being so large, tooling can be more limited than with a similar type of work in car production, although there would be very probably an increase in the cost of each component, due to this fact.

Tooling for press work and sheet metal work is another matter, as here car practice can be followed very closely, with two exceptions. These are:

1. The production of blanks by routers or spindles, where the material is a light alloy, as is usual with most aircraft structure components, in place of the expensive press blanking tools.

2. The forming and raising of components on cheap hardwood, zinc or steel formers using a rubber pad in the head of a hydraulic press instead of expensive steel raising and draw tools on heavy mechanical presses.

The only real reason for this policy is the question of tool economics, as there is a limit to the quantity of parts to be produced particularly when there is the prospect of changes due to modifications always just around the corner.

With regard to asembly jigs, there is a tendency for the major jigs for components, such as main planes, centre sections, centre fuselages, etc., to be made from heavy castings in place of the previous practice of building up jigs from ordinary commercial angle and channel iron. As far as their physical size will permit these castings are stress relieved by normalising in a very large furnace to make up for the normal well-known practice of weathering. As a result, jigs which are built-up in this manner do retain their dimensions and do not need continual re-checks with jig references and optical equipment, as was the current practice up to only a few months ago. An alternative scheme which has proved very satisfactory in practice is to fabricate box section pillars by welding up sheets of $\frac{1}{2}$ in. mild steel plate and carry out the same stress relieving process and use these in place of castings. In most cases these will come out cheaper than castings, mainly owing to the reduction in material thickness, in spite of the increased fabrication time. The assembly jig structures shown in Figs. 8 and 9 are constructed in this manner..

The principle of interchangeability on major units has been adopted throughout the aircraft industry and is now in the state of being extended to the smaller assemblies, such as undercarriage doors, detachable panels and so on, with the main object of facilitating repairs and service, although of course it does also help the basic production. From car experience we advocate an elaboration of this principle on the basic structure of any machine to the stage of detail interchangeability where possible. Whenever the detail, when completed, is rigid and not seriously affected by material tolerance build-up, it is completely fabricated and drilled accurately with all holes full-size and a maximum error on hole centres of $\pm .002$ in. If these limits be maintained it is found that the parts will go together more or less like a Meccano set, and as an illustration of what I mean, Figs. 8 and 9 show an actual component produced in this manner.

Fig. 8 is a photograph of a typical structure which is essentially suitable for building up by the full-size drilling of all mating holes, followed by the use of unskilled and semi-skilled labour on assembly. Another view of a similar structure is given in Fig. 9 which shows the cases where undersize drilling has to be introduced

to cater for dimensional differences caused by variations in the gauge of the materials within the range of B.S.I. tolerances.

Proof of the value of interchangeability from the repair angle was provided by a recent occurrence in connection with one of our products. We are producing centre sections of a machine which is finally assembled into a complete aircraft some distance away. One aircraft had an unfortunate landing and hit a tree stump with

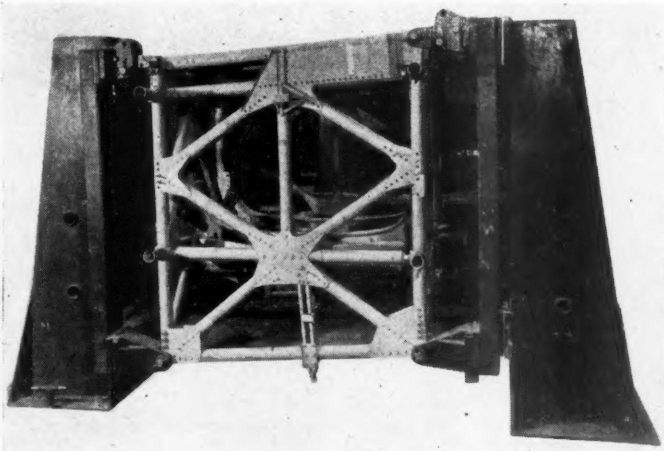


Fig. 8

one of its landing wheels at the edge of the aerodrome, bursting a tyre and tearing off the rear ends of the engine ribs complete with the undercarriage bearings. The orthodox treatment would have been to dismantle the aircraft on the field into its major components, remove to the flight shed and change the centre section, involving some 1,400 man hours minimum. The parent company knowing the state to which we had tooled the job, i.e., detail interchangeability, asked us if we thought, by sending two fitters with spare parts, some 30 items, it would be possible to effect repairs on site. We said "Yes," sent the two men and the parts, and at a cost of 45 man hours the job was completed. Equipment and facilities for fitting the replacement parts were very limited, the saving factor being our interchangeable component parts with full size holes.

A somewhat different technique has to be adopted when dealing

with less rigid components. Skin panels and stiffeners in a stressed skin construction are usually too big and flimsy to merit detail interchangeability, particularly when contours are involved, and in these cases combined drill and assembly jigs are constructed which carry stiffeners and skin panels clamped in the jig in their correct

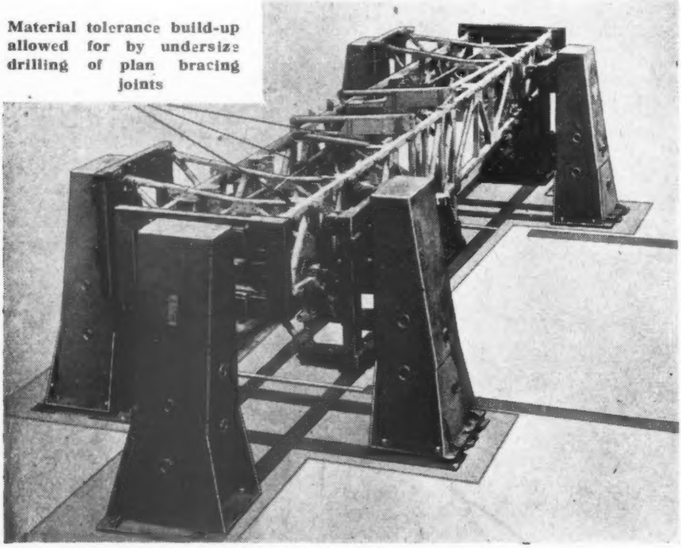


Fig. 9

relationship and to the correct contour while holes are drilled through all components together with the aid of a large drilling gate.

Interchangeability of the panel assembly is usually achieved by having a final trimming and picking up hole drilling operation effected as the final operation in a separate jig after the assembly had been riveted up or spot-welded.

So much for the more detailed side of tooling, but there are other important factors which support the accurate tooling theory. A big factor which has to be taken into account when taking up a new contract is the type of labour which it is intended to use on production. This point touches on a problem which is present today in all trades and forms of industry. The skilled men nowadays are very diluted with the input of semi-skilled and of female labour into factories. Although a proportion of skilled men is always necessary

particularly in key positions, the vast majority of labour is of the semi-skilled or unskilled type, and as such the need for very good, robust and accurate tooling brooks no denial. We are much worse off now than in peace-time as regards the standards of skill of operators and the knowledge that this state of affairs was bound to arise caused us to be even more adamant both on the large quantity and good quality of the tools we made than in pre-war days.

To illustrate these remarks on the quality of labour, I have some figures showing the changes which actually occurred on a particular project during this war.

MID-1941	END OF 1942 (*including dispersal to another factory*).
70% skilled workers.	16% skilled workers.
	28% semi-skilled workers.
30% unskilled and female workers.	54% unskilled and female workers.

The extreme dilution achieved by the end of 1942 would not have been possible without the detailed tooling advocated in this paper.

One point which we overlooked, relative to tooling, in the early days of this war was the weight factor when related to female labour and the obvious limitations as to what a female operative could lift. This point was very well illustrated when we transferred detail production from one area to another for dispersal purposes, where a much higher percentage of female labour was available. Considerable modification and lightening of jigs and tools had to be carried out; the point has now been largely overcome by the use of proprietary materials manufactured from bonded woods and plastics of various types on the bulkier types of jig.

We still use a considerable amount of plywood and hardwood such as ash or walnut in the construction of assembly drill jigs for minor assemblies but in all cases the jigs are mounted on a robust steel frame or trolley and all bearing surfaces coming into contact with components are metal faced with 16 or 20 SWG mild steel sheet. These jigs have been found to last through several hundred assemblies and are comparatively cheap to repair.

Maximum Allowable Tooling Costs.

Expenditure on tools must be carefully regulated; there is always a stage beyond which it is not sensible to go, and where extra tool expenditure brings a very small return in the saving on production cost. Harking back to car days for a moment, we struck this point on the fitting of a car bonnet. This unit is one of the most difficult things to fit satisfactorily on a modern car and one on which we never achieved real interchangeability, the main reason being that all the manufacturing tolerances on the body and on the chassis come

together at this point, resulting in no two car bonnets being exactly alike for attachment or clearance. It would have been possible to effect this interchangeability but only by rigidly controlling the dimensions of the body and chassis assemblies in very large and very expensive jigs. The cost would have been very high, so our alternative remedy was to train some specialist fitters who used to take only sixty minutes on average to fit these bonnets—a flat cost of possibly two shillings per car. At this cost you can fit quite a lot of bonnets for the several thousand pounds which the provision of suitable jigs would have cost.

As a further example in economy, it is quite usual in peace time for a car manufacturer to have to run the same car body for two or three seasons to recover the cost of dies for all the panel pressings, which might be anything from £60,000 to £200,000 dependent on the quantity of bodies to be produced and the stage to which tooling was carried

With this type of upbringing I feel that car manufacturers can teach the aircraft industry quite a lot about tool economics generally, but a large number of aircraft firms still argue that normally the quantity of machines to be made does not merit the high tooling costs involved in the foregoing principles.

A third factor, a wartime one, is the question of facilities available for the manufacture of tooling. The heavy overloading of all toolmaking capacity due to the rapid changes from one product to another must be taken into account when laying down a general policy for the manufacture of tools. Very few firms carry sufficient equipment and personnel to tool a project completely without resort to sub-contracting tool manufacture. Contrary to some firms, however, our practice is to sub-contract wherever possible tools which are of a straightforward type keeping the more difficult work in our own plant and under direct control.

In this direction car manufacturers have been fortunate in possessing groups of skilled workers, particularly bodymakers, who are perfectly at home at hand-working both wooden and steel materials. With the aid of this type of labour, temporary and very often permanent tools have been successfully and economically produced, enabling production to commence much sooner than otherwise could have been accomplished. Add to this also the fact that this labour group is ideal for starting up production on a new project, as had to be done every year in pre-war car days, and you will appreciate that firms in possession of this labour are well on their way to successful culmination of their efforts. Once the job is running, then semi skilled and female operators are drafted in place of the skilled labour which immediately becomes available for a new contract or project.

And there we must, I feel, leave tooling and pass on to the fourth major principle of car production.

4. Line Production.

Everyone is aware of the colossal quantities of motor cars which were turned out weekly, prior to the war, both in this country and the United States. These high quantities were largely made possible by the adoption of the line principle with the consequent detailed and accurate split-up of the work to be done at the various stages.

Line production, as you are aware, is in effect a system of production whereby the article to be produced moves progressively forward down a line probably on a moving conveyor or track while the operators virtually remain in the same place. The work to be effected is split up into the smallest elements consistent with the time cycle required and operators allocated to these small elements effect the same work on each unit, during which they become remarkably proficient in their own particular section of the work.

Naturally with the greater amount of detail required on aircraft and above all the space required, the rate of production has not reached car production figures. At the present time a typical figure of 25 major units a week could be taken as a basis for calculation, as this is happening in numerous factories. This means that roughly four units a day pass a particular station on the track and consequently the operator loading so calculated that each operator gets through his allotted work in two or two and a half hours (day shift only) or four to five hours where a night-shift is in operation.

So many aircraft firms still stick to the old principle of assembling a complete aircraft in a fixed position bay and working on it day after day, until eventually it does get finished. The big fault with this method lies in the fact that the numerous snags which crop up are cleared in their own time, and at the will of individual inspection and production personnel. Indecision is one of the biggest factors in holding up production, and I am afraid that with most of us there is a tendency to stall when an immediate decision on possibly a major point is requested from us.

When line production is used the decision is forced by the fact that the track will be held up unless that particular decision is made and metaphorically speaking the units progress themselves and push each other along and off the end of the track as a completed article. The alternative is a complete stoppage of production with the consequent spotlight of investigation focussed on some person or persons who are either over-zealous or inefficient in their own particular job.

With production methods of the above type, the planning or production engineer will inevitably be met with a demand from production department for a rectification or salvage bay for the

purpose of correcting such faults as occur, or the incorporation of last minute modifications. I do not advocate acceding to this request, or in a very short space of time there will be masses of 98% completed units all over the place. There are very few faults or modifications which cannot be cleared quickly once the decision is taken, and in some cases a special rectification group of people is formed to deal with all work of this type. Complete negation of this request for a sick-bay also keeps other departments, such as material control, progress, etc., on their toes with regard to the satisfactory supply of material at the right time, which is so necessary for a smooth production flow.

On the rare occasions that a really major structural alteration has to be made immediately, then tranship the units to another line after effecting as much work as possible on the original line. This can only be done providing that the floor space is available, and if labour be available also there is no reason why production should be interrupted except in the very initial stages. I have seen this principle put into operation in a factory building bombers whereby a considerable quantity had to be converted into transport machines. The machines were finished off in their original form, sent into the flight shed and then switched back on to a special modification line for the alteration to be effected. This method was continued until the original assembly line was re-planned and personnel adjusted to effect the alteration from the beginning of the line. In cases where floor space is not available then the only course open is to stop the track, replan it to cover the alterations or additional work and adjust personnel so that these alterations can be effected.

Extending this line principle idea, it is my firm conviction that given a continuation of large quantity aircraft construction in this country, before long moving conveyors will be used for assembling both major sub-assemblies and the final assembly of the aircraft. Criticisms of line production methods applied to aircraft assembly still exist, although they are nowhere near as numerous as in the early days of the war. This criticism is in most cases caused by the rather conservative attitude of the majority of firms in this country, no matter what their product, and also I feel by the fear that if aircraft are in truth mass-produced, then quality is bound to suffer which would be deplorable when you consider that quality alone, both of machines and men, saved this country from disaster in 1940. I would like to dispel this idea that mass production does destroy the quality of a product, because in actual fact it could be a means of improving same, owing to the increased facilities for research and improvement which large-scale production provides. I am not suggesting that for example a mass produced car which in pre-war days cost, say, £130 is anywhere near as good a car for performance or reliability as one costing three or four times that amount, and

built with less intensive production methods, but this is only due to the fact that the car manufacturer has had to get down to a price, and materials which he would like to have introduced have had to be excluded from the product. While aircraft production is on a more or less non-competitive basis, there is no reason at all why quality should suffer—indeed it should improve considerably owing to the standardisation of all the detail parts and various unit assemblies. In other words, you can be sure that when the job goes together all the fixing and attachment points have adequate material and are structurally sound, and that some individual fitter has not inadvertently pushed a drill through a member which is highly stressed, causing a weakening of that particular section, probably not observed owing to the super imposing of further equipment.

Thus I am convinced that with line production quality could and *would* improve until such time as various aircraft constructors started indulging in price competition additional to the friendly design rivalry which exists today.

Minor criticisms against line production cover :

(a) The incorporation of modifications.

(b) An adverse effect on the skill of operators.

(c) Large initial time lag in getting into production.

Dealing very briefly with these in turn, I would agree that modifications are, and always have been, the biggest source of trouble to the aircraft industry, but most of we initiates into the trade now realise they are a necessary evil if the final product is to be in the front rank as regards performance and purpose, etc. On a new machine, providing tooling is started before the prototype flies, you can rest assured that from 20 to 50 per cent of the tooling will have to be scrapped or altered. Some actual figures on one contract alone show 1,475 obsolete tools in stores against some 3,700 current ones. This is obviously a terrible waste of man hours and material, and in peace-time one would never contemplate starting on a project before the drawings were completed and the product proved and finalised. During the war, however, a somewhat different outlook exists, in so far as if only 50% of the original tools made are finally used for production, you do have the advantage of that 50% to form the backbone of the tooling for the machine, and you probably are six month's work nearer to actual quantity production because of this.

With regard to the effect of modifications on line assembly, we have found that by far the simplest and most satisfactory method s to have a suitable group of skilled people who can go along and introduce the modifications as they crop up, breaking in at any particular station on the track which may be convenient.

(b) With regard to the adverse effect on the skill of operators, the point made by the critics is quite true, but it applies so universally in all branches of industry that it is hopeless to expect to reverse this trend. What we have to do is to consider whether it is better to employ a larger number of people producing cheaper articles and bringing their products within reach of a wider range of people or whether one is to attempt to revert to true craftsmanship and comparatively low employment. It is perfectly obvious that the latter course is impracticable as we have gone too far along the road to mass production to turn back, but I would emphasise that there will always be the need for skilled people in tool rooms, in planning departments, and as key operators, making further extensions to existing apprenticeship schemes in this country very necessary.

(c) Regarding the large initial time lag in getting into production, here again the critics are quite justified, and I must agree that a considerable time does elapse before any production is forthcoming—I cannot deny the criticism because I have seen this state of affairs exist so very frequently.

Therefore, instead of denying this criticism we have to find a way of mitigating the time lag. Some companies refuse to do this, and stick rigidly to the principles of producing from tools, and until the final orthodox tools are made no production is effected. Their argument is that once tooling is completed, production will grow very rapidly and soon overtake any other manufacture on a similar project which has started on temporary tools and hand assembly. A company taking this attitude can only plan their tooling in batches, so that it is completed in a sequence of minor components which can be built up some time before the final assembly is commenced. Basically you know they are right in their assertions, particularly as regards reasonable flow production, but how many main contractors or ministries, want a flow or steady production initially ? Not really many. Sub-contractors are often held up after delivery of the first two or three sets.

I would advocate an intermediate course, and while the major and final tooling is going on, a hand-made batch of components should be made in an experimental section with the aid of, where necessary, temporary bending tools. It need only consist of five sets of parts, but the information gained helps considerably with the major tooling with which it is concurrently proceeding.

Naturally, additional expense is incurred in this direction, but as most major contracts nowadays cater for an initial "educational" batch, this point is not too serious, as would appear at first glance.

An educational batch of 5 to 10 sets would probably cost, per component, five or six times the eventual tooled cost of the same unit.

5. Time Study.

I only intend to touch very briefly on the question of time study of airframe assembly work, as obviously it is a subject which could have a complete paper devoted to it in itself. I find that there is a reluctance in the aircraft industry as a whole to use any form of watch timing for fixing prices on assembly work as distinct, of course, from the stop-watch timing of machine operations. There is really no sound reason for this reluctance as our experience shows that the timing of airframe work in all stages does improve efficiency by a considerable amount, although in some cases agreement has been reached with the Unions that timing of assembly work shall be effected with a watch not possessing a stop mechanism.

Personally I would prefer to use a stop-watch throughout the whole organisation, but there seems to be some misguided idea amongst aircraft workers particularly, that their time on this assembly work is going to be cut into split seconds, which obviously cannot be satisfactorily accomplished owing to the large number of variables which are continually occurring in the physical side of the production.

Some astounding results have been achieved where assembly work proceeded for some months on a day-work and " in lieu " rate basis when the change-over to a time-studied piece work price has been effected. Most noticable has been the saving in the labour force thrown up by the time study which in most cases has been between 40 and 50% of the total labour force engaged on any particular assembly at the time of the study. This obviously is a very important factor from a national point of view owing to the alleged present-day shortage of labour. Some actual figures show a reduction in personnel of 40% at the same time giving an increase in production of 20% after six weeks and 40% after nine weeks, together with average increase in earnings for the people remaining on the group of some 25%.

These figures are rather startling but are typical of what can be achieved with reasonably accurate study, apart from the saving which can also be achieved due to a more detailed analysis of the work to be performed which is so necessary for an accurate study. This detailed analysis always shows up improvements which can be made in some of the production methods, tools or equipment which the people are using, as we have always found it completely impossible to cover all angles on a pre-planning basis. All shops, and in fact individual operators, have their own whims and fancies

as regards types of rivet snaps, rivet dolleys, drilling attachments and so on—no one will ever cure them of this.

Obviously this subject could occupy a considerable length of time, but I feel I must leave it at this stage with a plea for an increase in the very sparse supply of time-study personnel and largely increased facilities from the education authorities and industrial organisations for the training of them.

Technical Points.

I am now getting near the end of this paper, but before closing I would like to mention briefly one or two of the more technical practices which are now being adopted on large-scale airframe production, which can trace their origin to adoption on a large scale on car production in the first place.

First we have spot welding technique. This last twelve or eighteen months has shown a very big increase in the adoption of spot welding for the assembly of the more easily handled sections of aircraft, such as fuselage and wing panels, fuel tank doors, cowlings, flaps. The process is similar in principle to the spot-welding of mild steel, except that a much shorter time cycle for the much higher welding current is necessary, only $^1/_{25}$th of a second instead of $^1/_5$th of a second, due to the more rapid fusion of the material. In addition, perfect cleanliness with no oxidation on the skins is necessary, usually effected by a chromic-sulphuric acid pickling process prior to welding. Naturally, the production of sample and test pieces plays a larger part than on car production, but, given time for further development, spot welding will almost completely supersede riveting on a suitably sized component, as it is faster and gives a better surface finish than riveting.

The mention of surface finish brings me to the second of the technical points which I wish to emphasise, as great efforts are being made nowadays to obtain a perfectly smooth exterior finish both to the wings and the forward portions of the fuselage of all fighter aircraft, thus obtaining considerable improvements in performance. As in car days, this finish is obtained by a filling and stopping operation, whereby all rivet recesses, joints between skins, etc., have a knifing stopper applied with a putty knife on top of previously sprayed coats of filler. The whole unit is rubbed down with water and very fine abrasive paper, and then finished off with further sealing coats of primer and camouflage. In some cases this practice has even been carried to the stage of polishing the final surface with rubbing compound and liquid polish, although the semi-gloss produced is not really suitable for aircraft use due to operational factors.

And here, as time is getting on, I feel we must let the matter rest. I have tried to show you that although the car industry has of

necessity learned a lot of other trades and techniques since the beginning of this war, so in turn has it imparted its knowledge, experience and production technique to other industries and in particular to the large-scale manufacture of aircraft.

This interchange of ideas is one of the few bright spots of the present conflict and I cannot help but feel it is for the ultimate good of industry and humanity that such an interchange can take place. I sincerely hope that the end of the war, which we all hope is not too far away, will not see the end of the co-operation which the war has built up between one trade and another—between the designer and the producer, between the large firm and the small one, and above all between we individuals gathered here tonight and the many thousands like us who desire to do something worth while and give value for money whatever our trade, profession or craft may be.

THE MACHINING OF NON-FERROUS ALLOYS AND THE APPLICATION OF SPECIAL MACHINE TOOLS

Paper presented to the Institution, Glasgow Section, on 9th December, 1943, *by G. F. Staples, A.M.I.P.E.*

THE object of this paper is to discuss the machining of aluminium most prominent of non-ferrous alloys in use today. The paper is mainly concerned with the machining of large Aero Engine Castings, with rather more emphasis on the machining side, than the applica-

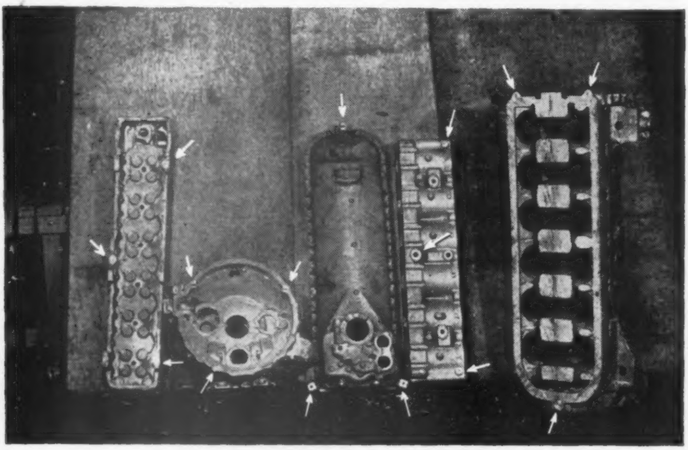


Fig. 1.—Jig Spotted Engine Castings.
Eliminating marking out and enhancing loadings and location.
NOTE.—Three jig spots in every case.

tion of special machine tools. The paper is generally presented through the eyes of a Planning Engineer comprising the approach to a complete production from blueprint to the final machined component.

Aluminium being a metal of great machinability, the full art of the engineer can find expression, and sometimes at relatively little cost in initial outlay for the results obtained. The abnormal

volume of aluminium being machined today has brought about special machine tool developments, mainly associated with the tendency to utilise tungsten carbides to full advantage.

Aluminium is being machined today in some factories at surface peripheral speeds of 14,000 ft. per min., with feeds in the region of 50 inches per minute. Certain schools of thought are convinced that such performances are not excessive, and in fact do not represent the limitations of ultimate cutting factors as applied to tungsten carbide tools.

The desire for high speed machining of aluminium has naturally brought demands on nearly all types of machine tools for improved

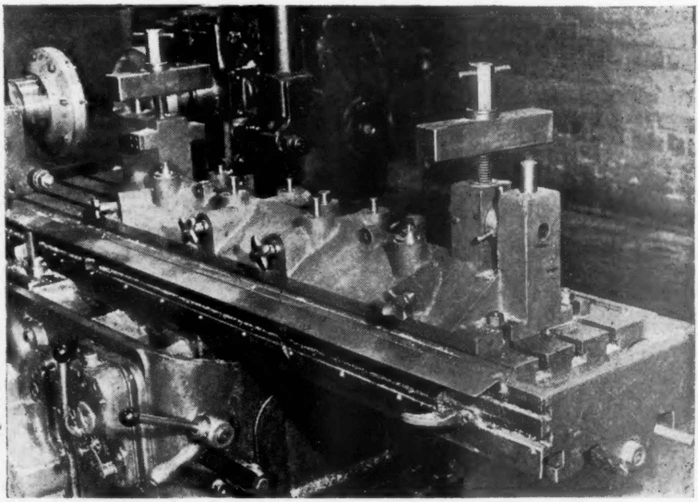


Fig. 2.—Cincinnati 34/60 Duplex hydromatic machining base and top of engine cylinder skirt.
NOTE.—Jig spot locations clean fixture design.

spindle design and high feed rates. Some machine tool manufacturers have produced machines running at spindle speeds of 24,000 rev. per minute, whereby by utilisating tungsten carbide the removal of aluminium is similar to the ease with which wood is machined, the finish imparted and the accuracy being first class. Contrary to the present modern and prototype experiments with negative tool rakes for machining ferrous alloys, the non-ferrous alloys need tooling with good positive rakes and exceptional chip clearance for perfect performance.

The acme for all machine tool set as working on aluminium must be the ability for the cutting tools to operate freely, with the ability to freely eject the cuttings away from the actual work point. When cutting stresses are imparted in the manner to cause undue compressive stresses as in orthodox face milling, the subject piece is very likely to distort when freed from the retaining fixture. It is our practice, therefore, to utilise advanced type milling heads with certain desirable features to overcome the possibility of undue compressive stress in machining. Typical example (Fig. 3).

The exploitation of speeds and feeds is most marked in modern

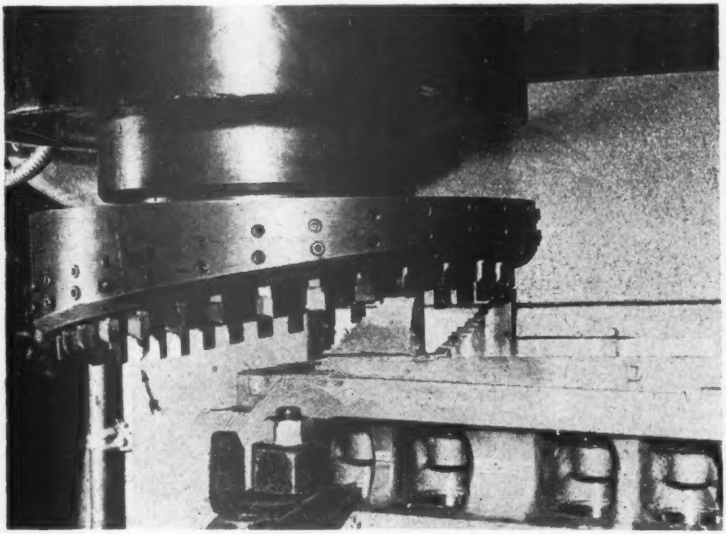


Fig. 3.—Specially Designed Milling Cutters.

Production milling service lugs from engine Cylinder Head. One cut at 1,000 r.p.m. 10 in. per minute feed. Maximum metal removed 2 in. depth. Surface is completely finished—requiring no extra cuts. Close up shows progressive development of cut and features of cutter. One tool marked takes finishing cut.

milling machines with possibility high speed boring machines a good second.

It has been found advantageous where possible to machine aluminium dry, to avoid the tendency of surface burnish, and the prevalent danger of locations packing up with swarf.

We recognise aluminium for ductility and machinability, and generally the application of coolant during high speed machining,

present a highly finished surface, but there is always a great hazard of tools picking up and causing surface scores. The general coolant when used is ordinary cutting compound, although paraffin is sometimes used, but it is not recommended as the cutting action becomes absasive and abnormal tool absorption is likely to result. Diamonds have been used for finishing, but these excel best on high speed boring and turning. It must be mentioned here that tungsten carbide operates extremely efficiently on similar types of work and is quite economical. Diamonds are not suitable for production

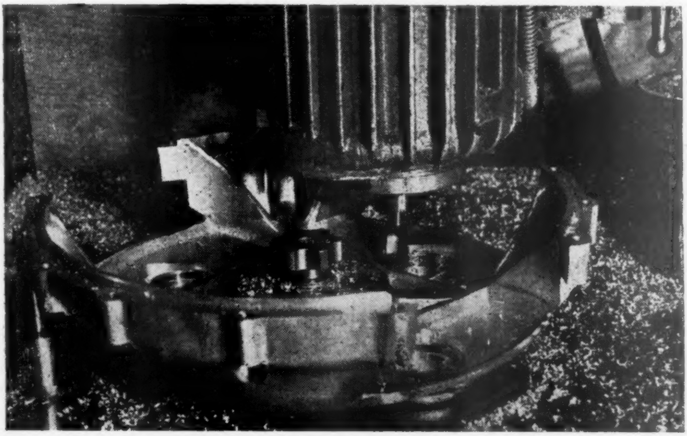


Fig. 4.—Wadkin L.U. fixed head router.

Machining three ball race housing faces in engine gearcase to fine limit depth. (.001 limit). Revs. 24,000 using tungsten carbide tipped special tools.

NOTE.—Extra fine finish on faces machined. Form traced from roller underneath plate in contact with similar form.

high speed milling on large Aero Engine Castings, for the general result is a scratched finish.

The diamond being the hardest cutting agent commercially known has one failing with high speed production milling, when the cutting facet is dull the finish to the work being machined appears to improve. The extreme hardness of the cutting edge is such that even near break-down the tool is really forcing the metal off in a series of ridges causing a highly burnished finish.

High Speed Steels are perfect cutting agents for use on aluminium being widely used for drills, shell end mills, form tools and broaches, etc. But it will be appreciated that the use of High Speed Steels

must lower operating feeds and speeds as compared to tungsten carbide employment.

Stellite is used extensively, particularly for form tools, heavy duty milling blades and special tools, where the application of tungsten carbide is difficult.

The aforesaid, therefore, covers some of the fundamental of

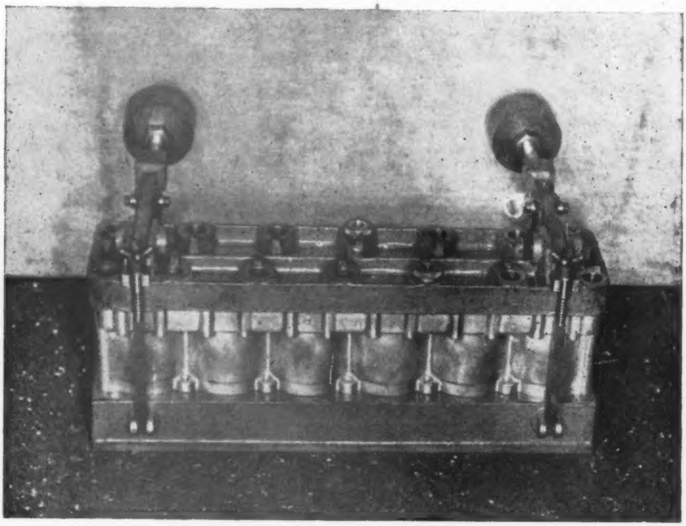


Fig. 5.—Exploiting jig and tool design to assist female labour with index jig tops and free access for loading component piece.

NOTE.—Jig plate and base proportions for economy and lightness.

machining as applied to aluminium alloys, and serves to establish a general basis indicating present day practice.

Planning from the Blueprint.

When viewing a proposed production piece on blue prints, the first reflection of the Planning Engineer will probably be that the designers have managed to make things harder in some aspects and particularly from the machining point of view. It is the immediate duty of the Planning Engineer to co-relate directly with the Design Office to alter the component drawings, if certain alterations can be foreseen which will assist production without detriment to the existing design.

The general policy covering the production planning of a new

component piece will be the complete issue of unit jigs and tools to cover a total sequence of operations entirely independent of special machine tools. This particularly applies if the components are required at fairly short notice, but it is also a safeguard against

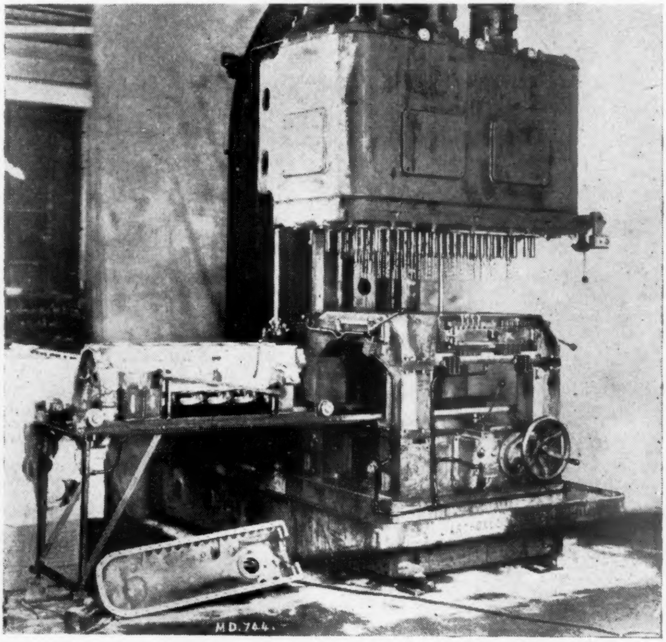


Fig. 6.—Archdale, size 5, Multi drilling machine. Drilling and counterboring 61 holes in engine crankcase and engine sump. This machine accepts two different components shown at left hand side of machine. Machine and fixture is completely interlocked.

NOTE.—Electro-limit latch at front of machine.

special machine tool breakdown, the employment of such unit tooling serving until repairs are completed.

It is advisable to introduce special machine tools into production when they have been thoroughly tried and proved correct to the satisfaction of the inspectorate concerned.

In this respect planning should take an active interest regarding the application of master receiving gauges.

It is recognised that certain difficulties prevail when inspection personnel depend entirely on standard precision instruments.

For with the multiplicity of fine limit dispositions accumulative errors do unavoidably creep in during a component check, and are of such a nature as to practically eliminate the chances of consistent readings.

According to the symmetry of the component design the Planning Engineer from experience should be able to estimate the likely chances of distortion and guard against this by correct machining sequences. Conditions vary for various castings, but it is quite possible, providing the above condition prevails, to finish a major face first and operate from this for 75% of the machining sequence. Success in this direction depends entirely upon early stock removal, and in certain cases peculiar to component design, it is a mistaken policy to finish a major locating face last. The reason for this policy is fairly obvious, for with complicated components with fine limit relationships, to destroy the whole machining by altering the datum location face last, is placing the complete machining sequence into hazard at the hands of one operative when the machining is about 100% completed.

Very little bedding is necessary after the machining of aluminium castings provided cutting tools are kept absolutely keen and operated at high speed rates and on a comparative feed basis.

A peculiar point which arises in connection with this super-finishing by machining is the fact that if machine spindles are gear driven the inaccuracies of gear mesh are reproduced directly on the finished machined surface. The recording is apparent, but not generally detrimental to the finish. However, it is the best policy when possible to employ either directly motorised machine spindles or " V " belt drives.

It will be appreciated that some such surfaces in abutment have to withstand pressures on test up to 600 lb./sq. inch, so really first class machining technique must be applied.

The Planner will be alive to the fact that an operational sequence that places an abundance of accurate operations together at one machining phase is almost certain to hold up production and prove a constant source of trouble. He should also insist un setting gauges with all equipment to enhance the advent of correct and speedy set-ups assisting the continuity of production. If there is any doubt about surface finish, he will provide a sequence allowing for a superior finish, a standard which can always be lowered without disruption to output.

In all things he should tend to the orthodox, but prototype upon the recommendations of the personnel responsible before initial introduction to production.

The following three facts the Planning Engineer must know to achieve a balanced operational sequence :—

1. The number of finished components required per week.

2. The average working week.
3. The actual operating efficiency of the production shop concerned.

The first two requirements are straightforward, but operating efficiency is generally gained from statistics and experience. A fair basis in most production organisations using a high percentage

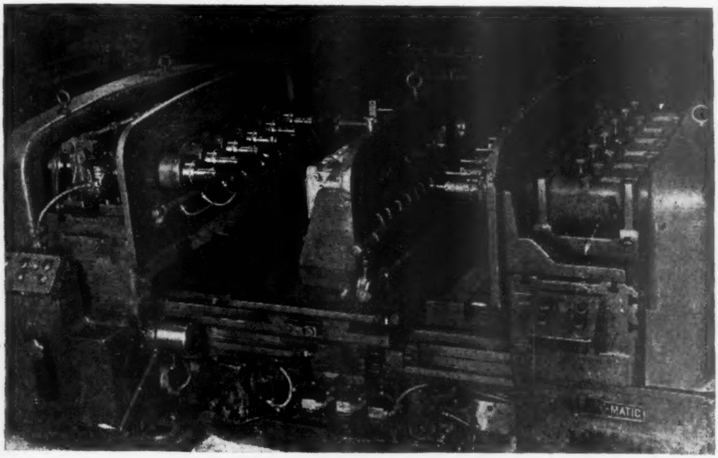


Fig. 7.—Heald 45 double ended borematic.
Finish boring 12 valve seat-housings in engine Cylinder Heads. Finish boring 12 valve guide-holes and facing spring pad faces.
NOTE.—Hydraulic index table and left hand end of machine auto retracting spindles on to hydraulic ratchet stops for positive spindle position.

of diluted labour is 75% efficiency. The factor is, of course, dependent upon various prevailing conditions, such as :

Whether operatives are paid by results.
The actual percentage of recognisable unavoidable scrap.
The incidence of absenteeism and major machine tool breakdown.
The ability of section personnel, such as Setters, Chargehands and Foremen.

A simple calculation derives the "floor cycle," the basis of all planned operational layouts. If the floor cycle is ignored, disrupted production will result in out of balance floor cycles, labour disruption, overloaded machine tools and unrequired component build up. The ideal operational layout meets the floor cycle equally or in exact multiples achieving accurate machine load balance.

With large aero engine castings it is essential as far as possible to achieve balanced line flow, enhancing the use of conveyors and obtaining generally a well-disposed machine section.

Line Flow.

When a line flow is conveyorised, there are two predominant methods concerning the disposition of the machine tools, both of which have highly controversial advantages when compared. There is straight line flow where the component progresses directly

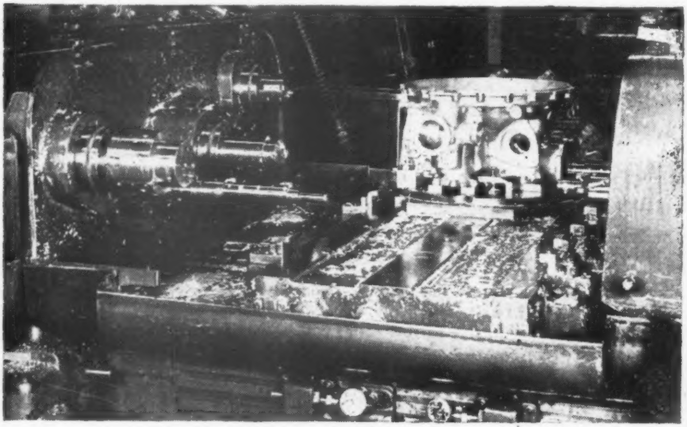


Fig. 8.—Heald 4½ Double ended Borematic.
Finish boring and facing engine wheelcase fine limit ball race housings.
NOTE.—Method of loading, indexing and clean quill design.

forward at all times. There is staggered line flow where the component passes directly to a machine opposite and thereon in sequence throughout the line. The following factors control the ultimate line out selected :—

1. Ability to build up production at a desired stage.
2. The bulk of the piece in production.
3. The actual distance the piece travels in transit from the initial to the final operation.
4. The actual floor space occupied by the various machine tools.
5. The rela ionship to the various services and the ability to introduce such economically, i.e., compressed air, electrical supply, coolant and swarf removal, overhead runways and machine maintenance, etc.

6. Where it is desirable for the piece to enter production and ultimately finish in relation to the production shop as a whole.

With a knowledge of the aforesaid, the Planning Engineer decides the first casting locations.

The initial locations for large production castings should be "jig spots," the disposition of which should be decided in co-relation with the foundry. These should be established after due consideration at the widest extremities of the piece and should take the form of not more than three drilled and spotfaced holes. The Foundry should position these with specially arranged equipment, and in doing so, utilise their intimate knowledge of the particular casting, taking into consideration the general disposition of all important wall thickness, general outlines, and critical core positions.

The advantages gained are fairly obvious, then wall sections in production are a rarity, and all such troubles are confined to the source. There is the added advantage that the initial machining locations are secure and the inciden' of accident is almost unknown (Typical example Fig. 1).

The machining sequence with large aluminium castings can be analysed as follows :—

Milling : Important oil seal faces, joint faces, datum faces, and bearing surfaces. Three machining cuts : rough, semi-finish and finish.

Speeds and Feeds : These are usually governed, particularly on the larger types of machines, by considerations of spindle design which may prevent the full exploitation of T.C. Tools, but we use : Rough, from 750 to 1,000 r.p.m. using T.C. Tools at feed ratio from 10 in. to 15 in. per minute.

Metal Removed : From $\frac{1}{8}$ to $\frac{5}{8}$ in.

Speeds and Feeds : Semi-finish from 1,000 to 1,500 r.p.m. using T.C. Tools at feed rates of 15 in. to 25 in. per minute.

Metal Removed : From .010 to .015.

Finishing cuts similar to semi-finishing.

Boring : Ballrace housings, fine limit bush bores and gear centre bores. Three machining cuts when over 2 in. dia. referred to with current practice as follows :—

Pre-oping, semi-finishing, final borizing.

Speeds and Feeds : *Pre-oping*. From 300 to 500 r.p.m., dependent on the type of tooling that can be applied, feed rates from .003 to .006 per rev.

Metal removal : From $\frac{1}{4}$ in. in dia. to 1 in.

Speeds and Feeds : *Semi-finishing.* From 600 to 900 r.p.m. with T.C. Tools at feed rates of from .002 to .003 per rev.

Metal removal : From .030 to .040 in dia.

Speeds and Feeds : *Finishing.* From 600 to 900r. p.m. with T.C. Tools at feeds rates of from .002 to .003 per rev.

Metal Removal : From .010 to .020 on dia. and .010 on face plunging.

Turning : Important oil seal faces, etc. Three machining cuts, generally the same allowances as for milling but finishing cut is usually in the region of .005. Peripheral speeds of 2,500 ft./min. or higher according to the factor of safety.

Tapping : Most tapped holes are generally plug tapped outright, using machines with controlled pitch feed and taps with the minimum number of flutes, little or no circular relief, one thread and half lead and straight flutes. Spiral flutes taps and interrupted thread taps have been tried without success. Under $^5/_{16}$ in. dia., taps generally have two flutes only.

Surface Grinding : Surface grinding success depends entirely on wheel and cutting lubricant selection, both of which are vitally important. General grinding allowance from .003 to .004, of metal. General wheel speed at face—8,000 ft. per min. General plunge per stroke .0005. General Feed rate 300 in. per minute. Surface grinding of aluminium is generally desirable when steel inserts are fitted to bring the entire face absolutely flush for the abutment of the mating piece.

Reaming : General allowance for most size holes from .010 to .015, feeds dependent on hole sizes. A fast feed generally produces a first class finish, particularly if the reamers are honed, and have good chip clearance, straight or right hand flutes, small land around .015 and little lead.

Drilling : Holes with limits from +.003 and under $\frac{1}{2}$ in. in diameter are generally drilled outright. Holes in this class over $\frac{1}{2}$ in. in diameter are generally drilled in two stages, the final drill being either three of four fluted.

Relatively high speeds are used varying according to hole size from 250 to 2,000 r.p.m.

Drill cone angles are best around 118° to 120° and the drill point should be well thinned to avoid spreading the metal with the high feed rates.

Quick spiral drills are sometimes used, but these operate better when over $\frac{1}{2}$ in. in diameter.

Drills like reamers should always be used in quick change collets as these allow .002 or .003 float, enabling the tool to take bush align-

ment without undue interference, when in use on single spindle drilling machines.

Stepped drills can be used to advantage but perform best on multi spindle machine with controlled feeds.

Drills should awlays be selected if possible to take advantage of $\frac{2}{3}$ of the whole limit, giving a reasonable allowance for drill wear.

Great care should be taken when cutting drills down for special purposes as some manufacturers allow .001 per inch taper on flute size for clearance.

Coolant should be used for all drilling without exception.

This résumé of machining practice has been interposed to indicate the stage sequences that the casing will be subjected to, during production.

Inter-operational Heat Treatment.

All engine aluminium castings are initially heat treated before introduction to machining. But, there are exceptions with certain castings where inter-operational heat treatments are very necessary. Such heat treatments are referred to as Stress-release, and occur early in the machining sequence when the bulk of surplus metal has been removed.

Components such as cylinder units which function in a heated condition and are subject to raised temperatures during production flow for the fitment of various inserts, are stress-released. Stressed release temperature is between 160 and 170° C., soaking time varying from 6 to 8 hours according to mass.

Furnace temperature variation during this process can cause growth of the component and may be as much as .001 per inch. Distortion also takes place but this generally is not excessive. Success in this direction can be attributed to correct suspension in the furnace. After stress release the components are allowed to cool freely in air.

All major datum locating faces are machined and corrected directly after stress release to avoid complications. It is usual also to pressure test the castings after stress release, by blanking off all apertures with rubber, and introducing compressed air into the water coolant and glycol cavities whilst totally submerging in hot water. Cracks, fissures and blow holes are revealed by the escaping air passing through the water to the surface.

Insert Fitment.

Inserts screwed into these components are generally steel, but bronze inserts are by no means an exception. With very few exceptions all threads are truncated to ensure effective fits on thread frank form. All such fitments are run in with interference fits which are generally around .002.

It is usual with large inserts to heat the component to around 150°C. thereby reducing the stress interference and with the subsequent contraction, achieving a perfect bond. All inserts are seated into hand cut conical seatings, perfectly concentric to the adjacent threads. With small aluminium components it is the general practice to heat in hot water or boiling oil, to lessen the interference

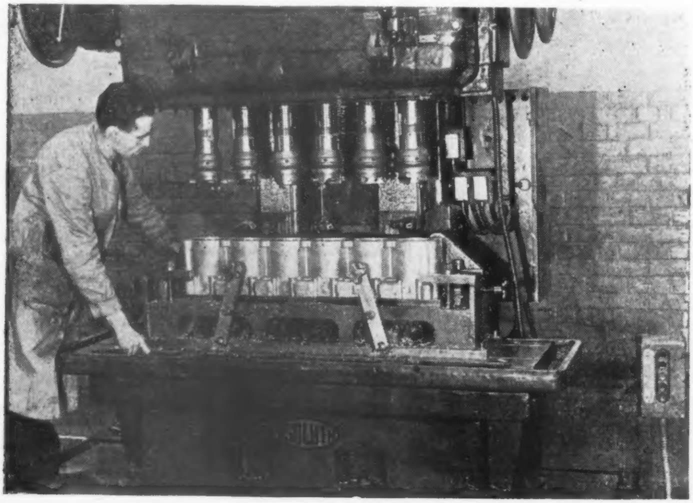


Fig. 9.—Asquith six spindle Borer.
Rough boring engine cylinder skirt. Locations jig spots and bottom machined face.
NOTE.—Clean fixture design.

for running inserts. Drivers for inserts should have ground threads and small mechanical advantage to avoid damage to insert threads in general.

Fettling and Polishing of Castings, etc.

This art, not generally fully appreciated has been brought to a high standard with aero engine castings and functions to remove all foreign matter, sharp edges and generally cut to within fair limits complicated port openings.

Fettling entails the use of rotary files and cutters attached to flexible driven shafts, various types of wire brushes are also used and generally referred to as scratch brushing. Felt and cloth bobs running at high speeds remove sharp edges without damage to finished machined faces.

Such a high degree of skill has been attained with this art that even certain machining operations have been taken over, with excellent results, such as gear tooth rounding, chamfers on complicated profiles and awkward contoured apertures.

Having thus lightly dealt with some of the essential services which are of great importance in operational planning, a few words on location are necessary.

Locations should always be selected on the widest extremities of the castings and throughout the machining process should change as

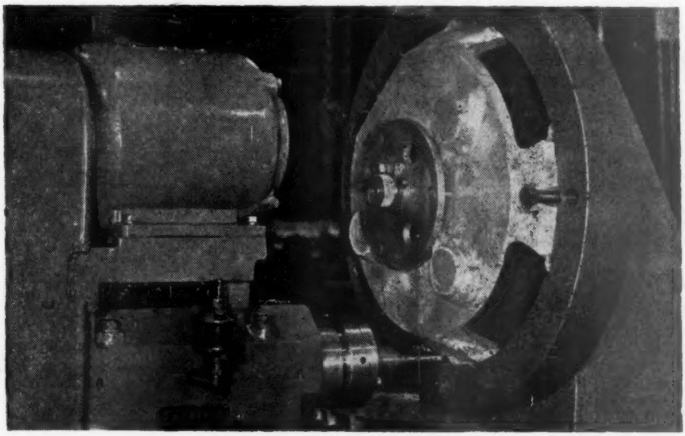


Fig. 10.—Excello Fine Borer Model 2112A.

Fine boring engine gear case fine limit dowel holes. Three dowel holes indexed bored. Compressed air swarf clearance blowing through back of dowel hole. Machine also accepts mating component piece.

little as possible. All location holes should be reamed or bored and held to fine limits. All surface locations on jigs should have local contac only to avoid trapping swarf. As casting should never be loaded on to location pins, the pins should be hardened and lapped and engage the holes by plunge action. Location pins whenever possible should locate on one full pin and one pin relieved in the appropriate direction. A location hole in aluminium can be used under these conditions 10 or 20 times, without undue sign of wear. When locating from cylinder bores it is sometimes advisable to use three locations, the two extremes unilateral and the centre location lateral to distribute errors evenly.

Jig and Tool Design.

The Planning Engineer if he is thoroughly competent should have control over the jig and tool design office. To enable him to exercise control and insist that layout sequences are rigidly adhered to. On any other basis, unless the Chief Jig and Tool Designer is 100% co-operative the production will ultimately suffer.

With the high production demands in factories today the operative labour should not be subjected to undue fatigue by cumbersome jig and tool design. Large aero engine castings require substantial

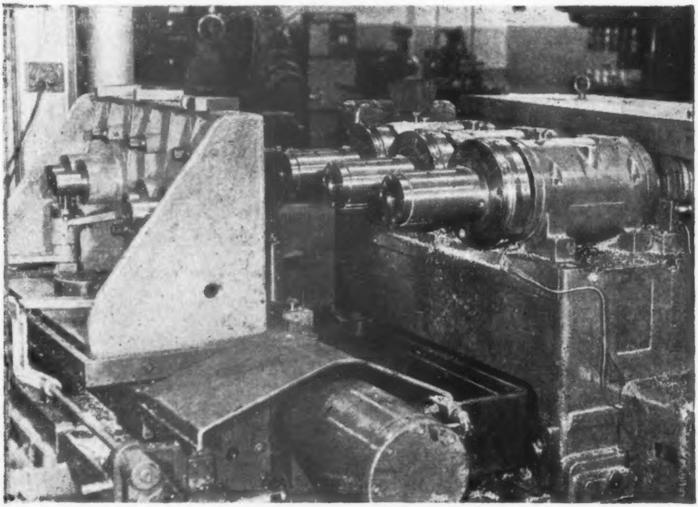


Fig. 11.—Heald 45 Single Ended Borematic.
Fine boring engine Cylinder Skirt. Table makes hydraulic index to complete six bores, hydraulic outfeed tool heads in quills for recessing piece.
NOTE.—Fixture gauging component piece by plunger action into bores.

jigs, therefore whenever possible jig tops are counterbalanced to raise automatically upon release, enabling the operator to remove the component piece. (Typical example Fig. 5). Loading rails, work ejectors, collapsing clamps and free access should always be first principle.

Sympathetic consideration in design as to the limitation of operative effort ultimately results in increased production. The advent of female labour gives good ground for exploitation of new designs, the adherence to obsolete practice means only part utilisation of the operative effort available.

Consideration with large index jigs should be whether two components can be loaded to balance the jig. Coolant flow where possible should be directed through holes drilled in the jig plates, directing on to the position subject to machining. Jigs should be well troughed to accommodate coolant overflow. Slip bushes should be easily removable but retaining pins that withstand careless operators have yet to stand the acid test of some present day operatives.

Bush tops upon which running stops dwell should be stellited, and if possible the stellite should extend into the bush bore at both ends. Running stops should also be stellited as this brings about a perfect and lasting arrangement not likely to be broken down by heavy handed operators.

Important form tools, spotface tools and counterbore tools should never be operated through hardened steel bushes, if it is possible to pilot the tools from the component piece. In such cases control on radial drilling machine should be achieved by dial indicator reading from the work spindle.

Liner bushes should be used extensively, even for fixed bushings where bush life may be relatively short and replacement frequent. Where it is applicable with clamps, the adjustment of one should adjust its opposite by virtue of an interlocking bar to which it is attached. If it is at all possible all clamps should be controlled from one hand wheel, thereby eliminating the need for spanners and individual adjustment. Location spigots should always be at the minimum size possible to assist easy loading of the piece. Hardened arbors should not run in hardened bushes above critical speeds, otherwise seizure will result. In all such application the arbor should be bushed with a bronze bush and replaced at signs of wear. Pins in use for index locations should be diametrical and parallel. Taper index pins should not be used where there is a possibility of swarf entrance.

Electrical limit switches can be used to advantage to indicate incorrect loading, if in circuit with a solenoid operating a starting control. Dial indicators should be used extensively and master arrangements should be provided for the setting of these.

Important forms, tapers and co-relative elements should always be traced from a hardened master with tools in a set battery. Small tools should have the least possible number of flutes, good rakes and above all ample flute clearance. A good point to remember in small tool design is always to keep at least two flutes in the cut, i.e. milling application, etc. The maximum rigidity of tooling cannot be stressed too deeply, for this is a frequent failing with small tool design. Tools should never be provided with running rollers for tracing around hardened profile plates, if it is possible to provide a fixed roller attached to the non-rotating portion of the machine spindle nose.

These few points touch the fringe of jig and tool design as applied to non-ferrous alloy machining.

The Application of Special Machine Tools.

How can we define a special machine tool and its place in modern industry ? How desirable are special machine tools ? How are they applied and what re-construction is necessary to meet their advent ?

Fig. 12.—Natco 3BL Holesteel Multi Drilling Machine.
Drill 10 holes in engine cylinder skirt.
NOTE.—Rotating index table holding three units. Piece drilled from each side.

The true special machine tool is generally a multi-purpose machine that is specially tooled for a particular operation, or series of operations on a production piece, and it does not generally have the immediate ability to accept a different set of operations without considerable alteration.

Special machine tools are desirable because of the following outstanding advantages :—

1. Great saving in small tool life.
2. Skilled operators unnecessary.
3. The limited production floor space occupied.
4. Absolute consistency of work produced.
5. Exceptional low floor times compared to standard methods.

6. Low incidence of machine tool breakdown.
7. Lighter load on maintenance regrinding of small tools.

Special machine tools are applied where the production rate is sufficient to warrant ther economical introduction. Little or no reconstruction is necessary to accept special machine tools, because

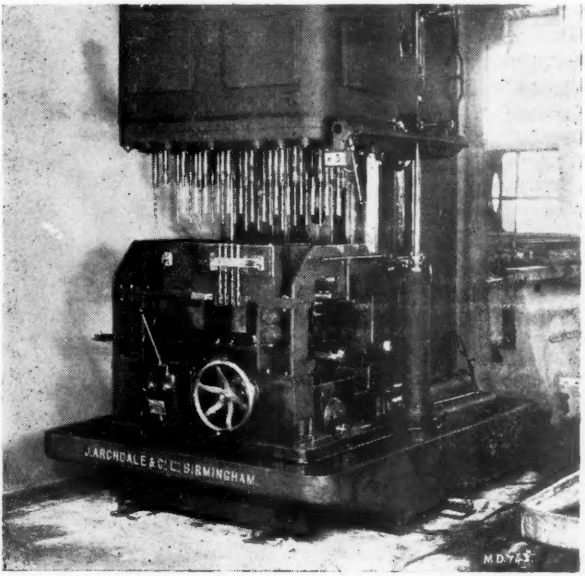


Fig. 13.—Archdale, Size 5, Multi Drilling Machine.

Drilling and counterboring 22 holes in engine Crankcase. Component piece is indexed for counterboring.

NOTE.—Electro-limit latch with four drills at front of machine, removed from spindles above to ensure fool-proofness of set up.

such introductions are generally an easement to all existing services. The special machine tool category covers a vast field of which the following can be included :—

Multi-drilling machines of all types. (See Figs. 6, 12 and 13).
Controlled, pitch multi tapping machines. (See Fig. 14).
Multi boring machine both inclined, horizontal and vertical. (See Figs. 7, 8, 9, 10 and 11).
Multi purpose milling machines. (See Fig. 2).
Special multi applications encompassing a series of operations.

All these machines combine hydraulic and electrics using valves, pumps, cylinders, regulators, limit switches, solenoids, time relays and a multitude of devices making fully automatic cycles. These machines, products of combined hydro-electrics, are a heritage of years of advancing experiment, now available to establish new methods and constituting an undeniable asset to modern production engineering.

The modern high speed production boring machines with an infinite variety of cycles such as rapid approach, into feed, jump cycle, into feed, into facing cycle (whether out-feed, feed or plunge) back off from tools, raise piece to avoid drag line and rapid withdrawal is a fair example of hydro electric exploitation, commonly used with non-ferrous production.

Such machines are either open circuted machines, with the oil bleeding through valves opposite to the feed side of the operating cylinder, or closed circuited machines with the oil in contant relay through variable delivery pumps, etc. When faces are too large for plunge facing hydraulically operated slides with an outfeeding motion come into play, the whole of the cycle being in a state of interlock whilst such is functioning. It is not unusual for such boring machines to have hydraulically operated cross index slides, reproducing to close limits a series of holes on constant centres. Boring applications are not confined to plain bores ; by special arrangements fine limit tapers are bored, conical seatings plunge finish, grooves cut by out feeding tools, spherical internal and external forms turned and a multitude of other similar operations.

These machines function to bore all fine limit gear centre bores on aero engine castings, cylinder line bores, valve seat bores, ballrace bores, control shaft bores, and in fact operate generally whenever it is deemed necessary to fine bore. Even dowel holes down to $^5/_{16}$ in. dia. are being successfully bored with economical results in large aluminium casings. (Refer to Fig. 10).

The general proportion with deep hole snout boring on unpiloted boring heads is the ratio of the hole dia. to its depth. To be successfully fine bored this ratio should not exceed 6 to 1. Fine limit adjustment is generally achieved by slackening the quill and turning it either clockwise or anti-clockwise a small increment, as the suspension is generally eccentric by a few thousandths. for this purpose.

We will now pass to the applications of multi drilling. Multi drilling frames again exploit hydraulics and electrics to the full with a variety of cycles. A typical example is start spindles, rapid approach, into feed, rapid retraction (for swarf clearance), rapid approach, into feed, or to position stop, spindle dwell, rapid returns, stop. Multi drilling machines carry from 2 to 120 small tools, with spindle speeds to suit, drill size by virtue of gear cluster head design.

In all application it is usual to have a guide plate, fully bushed, generally located on the fixture. But there are applications where the guide plate is part of the cluster head. A well-tooled multi drilling machine will reproduce consistently to .001 centres providing

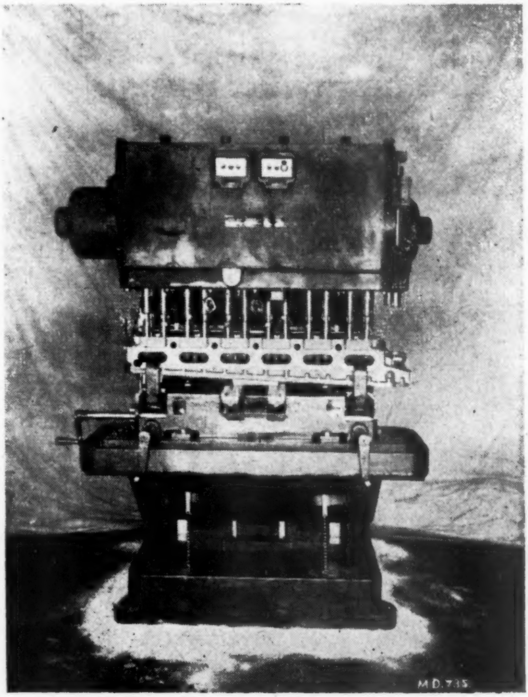


Fig. 14.—Archdale 24 Spindle Multi Tapping Machine.

Controlled pitch tapping of inlet and exhaust valve seat bores. Spring loaded and special sleeve torque safety spindle drives. When tap becomes over heavy to drive, the spindle concerned idles. Table feeds up to tapping position.

small tools are maintained in good condition. Step drills can be exploited to the full, their use is enhanced, operating under controlled conditions. The main limitation with multi drilling is the spacing between hole centres, most manufacturers will not space below $1\frac{1}{4}$ in. Such applications are spread over two machines locating from common centres.

Some manufacturers standardise spindle suspensions in ball or roller race form, whilst others employ bronze housings both of which correctly applied are efficient. Most modern multi drilling machines convey spindle motion through the main drive box by universal joint rods, for continuous production the angularity of these should never exceed 10°. Cluster head gearing should be completely oil bathed and either helical or plain spur gears, the former being generally the most efficient. It is not always necessary to auto retract on deep hole drilling for providing generous allowance is made for swarf clearance and coolant introduction, the hole finish is first class.

Multi drilling is not confined to vertical applications, by employing in feeding heads a multitude of operations can be accomplished. Speeds should be as economical as possible to avoid undue wear on multi cluster head bearings, the gains in cycle time are generally sufficient to allow lower feeds with resultant consistency of finish and accuracy. Mal-alignment of multi drilling fixtures and cluster head details has a disastrous effect on the universal drives which quickly overload and fracture.

The day is not far distant when multi drilling will have to receive a first priority consideration with most production issues.

Whether machines are employed with adjustable slip spindles or fixed centres is of local importance, but adherence to certain principles and standardisation brings the cluster head changeover within economical limits enhancing their application and paying dividends to those courageous enough to employ.

These remarks are not particularly directed at the large concerns who have experience of such machines, but the medium and small firms who produce components on fairly extended schedules.

Multi Tapping.

The extensive use of multi tapping equipment with mass produced components brings to the forefront machines designed to eliminate operations generally the cause of considerable trouble.

Such machines of the multi spindle type are generally controlled pitch with special mechanisms to cater for overloads during tapping, and spindle auto-reversal within close limits.

Special machine tool advance will continue phase by phase employing electric hydraulics and compressed air, ultimately reducing the price of commodities of popular demands to within the reach of a greater proportion of the people.

From the major efforts in the sphere of aero engine manufacture we have employed specialisation and have learned how to economically apply such. We must take advantage of this knowledge

so gained and employ it to the fullest extent to enhance our production of the future.

In closing this paper let us pass an appreciation to the machine tool mancufacturers who strive to achieve a common end producing master war weapons and are an indirect issue to the public eye because precedence is nearly always given to the articles such machines make possible.

Research Department: Production Engineering Abstracts

(Edited by the Director of Research).

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

EMPLOYEES, WORKMEN, APPRENTICES, ETC.

Apprentice Craft Selection School, by P. B. James. (*Industrial Welfare, May-June, 1944, Vol. XXVI, No. 294, p. 76*).

School opened by The Brush Electrical Engineering Co. Ltd. in August, 1943. All boys before being indentured to the company as trade apprentices, serve six months in this school. School premises. Training schedule. Equipment. A list of products. Progress records. First results.

FOUNDRY.

The Centrifugal Casting of Gear Wheels. (*Z.V.D.I., Vol. 88, No. 7/8, 19th February, 1944*).

Centrifugal castings made of steel, cast iron and some other metals are generally stronger than those obtained by the normal process. In addition there is less wastage of materials and the mould is simplified, thus reducing cost in mass production. The process was originally applied to tubes. Cylinder liners, valve seats and brake drums soon followed and during the last few years centrifugally cast steel gear wheels have received wide application. Some of the steel dies employed for this purpose with vertical axis of rotation are illustrated, suitable for either single or stepped gears. The steel die is generally made of two parts, the lower part being rigidly attached to the rotor, whilst the removable upper portion is held in position by a system of pivoted levers which lock under centrifugal action. Before closing the die, a sand core is inserted in the lower part which produces the necessary recesses in the gear wheel and also protects the die from the impact of the molten steel. It should be noted that the external portions of the wheel must be in direct contact with the steel die. Similar inserts are provided in the more complicated die illustrated. A composite unit of 18 dies of this type will produce nine stepped gears per minute. Centrifugally cast gears have the same strength and behave in practice just as forged gear wheels.

(*Communicated by the Ministry of Aircraft Production*).

GEARING.

The Lubrication of Gears and Gear Boxes—I, II, III, by E. V. Paterson, (*Mechanical World, 5th, 12th, 19th May, 1944, Vol. 115, Nos. 2992, 2993, 2994, pp. 505, 533, 561, 15 figs.*).

Part I. Qualities required of lubricants and methods of application. Lubrication to reduce friction and dissipate heat. Causes of friction: (1) Sliding friction. (2) Oil-drag. (3) Oil churning. Reduction of friction or temperature. Viscosity required. General procedure is to select an oil

having a high or low viscosity according to whether sliding friction, oil drag or churning loss is the criterion. Examples. Other properties required by the lubricant. Resistance to oxidation. High thermal conductivity. Adherence. Selection of correct lubricant for spur or helical gearing, bevel gears, worm gears.

Part II. The application of gear oils. Splash and spray. Lubrication of gears. Examples of applications to straight spur, helical, bevel and worm reduction gear boxes.

Part III: Lubrication of bearings. Methods: (1) Grease lubrication. (2) Oil-chain and oil-ring. (3) Gravity feed. (4) Forced feed. Wear of gears due to overheating. Pitting. Even wear. Tearing of the gear surfaces. Extreme pressure lubricants. Changing the lubricant. Appearance of lubricant a good guide.

Infinitely Variable Gears for Machine Tools, by H. Schopke, (*Z.V.D.I., 11th December, 1943, Vol. 87, No. 49/50*).

The article deals mainly with mechanical and electrical drives. P.I.V. and Heynau gears and their characteristics. Leonard type with both field and armature control and applications.

(*M.A.P. Abs. 121/10, is given in Automobile Engineer, May, 1944, p. 210, Aircraft Production, June, 1944, p. 300*).

JIGS AND FIXTURES.

Jig and Fixture Practice, by H. C. Town, London, 1944. [*Paul Elek (Publishers) Ltd. 10/6 (by post 10/9). 112 pp. 5 in. × 8 in.*].

Review of this newly published book, which surveys present-day methods and equipment.

(*From Mechanical World, 12th May, 1944, Vol. 115, No. 2993, p. 535*)

MACHINE ELEMENTS.

Machine Tapers—I and II. (*The Machinist, Reference Book Sheet, 29th April, 1944, Vol. 88, No. 3, p. 19E, 8 figs.*).

American Standard for self-holding and steep tapers. Nomenclature. Basic dimensions. Dimensions for tang drive with shank retained by friction and tang drive with shank retained by key.

Roll Neck Bearings, by P. M. Macnair. (*Sheet Metal Industries, May, 1944, Vol. 19, No. 205, p. 803*).

A detailed review of a recently published book, dealing with economic and operational factors. Plain metal bearings. Synthetic resin bearings. Fluid film bearings. Roller bearings and other types.

The Principles and Uses of Electro-Mechanical Vibrators, by R. E. Blakey. (*Machinery-Lloyd, 13th May, 1944, Vol. XVI, No. 10, p. 37, 6 figs.*).

Definitions. Fundamental principles. Half-wave rectifiers. The construction of electro-mechanical vibrators. Applications of horizontal type vibrators. Applications of vertical type vibrator.

Direct-Current Adjustable-speed Drives for Machine Tools, by G. A. Caldwell, (*Machinery, 11th May, 1944, Vol. 64, No. 1648, p. 515, 3 figs.*).

Use of a rotary voltage regulator in a normal adjustable-voltage control scheme, giving wide speed range up to 120:1, at constant torque. Comparison

with : series variable-voltage drive, self-excited adjustable-voltage drive, conventional adjustable-voltage drive, and electronic adjustable-voltage control.

Magnetic Filters. (*Automobile Engineer, May, 1944, Vol. XXXIV, No. 449, p. 182, 2 figs.*).

Equipment for cleansing lubricating oils, cutting fluids, coolants, etc., consisting essentially of a permanent magnet enclosed in a cylindrical non-magnetic case. Description with example of application and performance.

MACHINING, MACHINE TOOLS.

Estimating Production Times. (*Machine-Tool Review, March—April, 1944, Vol. 33, No. 189, p. 27, 7 figs.*).

Planning of production on Herbert capstan and combination turret lathes. Essentials required for preliminary planning. Table of operation times for various movements.

Deburring Aluminium and Light Steel Parts, by G. O. Rowland, (*Iron Age, 27th January, 1944, Vol. 153, No. 4, p. 65*).

(*Communicated by the British Non-Ferrous Metals Research Association*).

Automatic Thread-cutting Device for Ordinary Lathes. (*Mechanical World, 26th May, 1944, Vol. 115, No. 2995, p. 579, 1 fig.*).

Thread-cutting device for the automatic production of threads of triangular and of Acme shape of any length and diameter. Characteristic data. Time saved.

CHIPLESS MACHINING

Precision Thread Rolling with Flat and Cylindrical Dies. (*Machinery. 1st June, 1944, Vol. 64, No. 1651, p. 589, 18 figs.*).

High production, increased tensile strength, and superior surface. Historical. Use by the aircraft-engine industry. Flat dies system and recent improvements. Newer method using cylindrical dies. Types of machines available for both processes. Practice of Wright Aeronautical Corporation. Blanks centreless-ground in two operations. 100% check of the blank diameters before thread rolling. Size of the blank and tolerances necessary. Cylindrical-die thread rolling machines for close-fitting studs having a lead end. Advantages of process for good quality and properties. Die failure of both types. High output. Essential parts of typical thread-rolling machines and their functions. Examples of products.

The Design of Stampings for Quantity Production, Part III. (*Machinery, 4th May, 1944, Vol. 64, No. 1647, p. 487, 21 figs.*).

Part III. Drawn or formed notched parts. Notches close to edges of flanges. Notches in straight channels, angles, curls, double folds, or bends. Holes : blanking and perforating ; perforating in flat square-sheared blanks ; perforating after stamping ; perforating and trimming ; drop-punch method ; relative cost. Locating holes in stamping designs. Holes less than the stock thickness. Clearances. Extruded holes for different purposes. Flanging for butt welding, brazing, or soldering tubes or shafts. Lanced holes. Louvres.

Mechanics of Sheet Metal Bending, by W. Schroeder. (*Trans. Amer. Soc. Mech. Eng., November, 1943, Vol. 65, No. 8, p. 817*).

Discusses basic mechanical phenomena occurring during the bending of sheet metal, and derives mathematical methods for predicting the behaviour during and after bending. Refers to 24ST Al clad.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Methods of Forming Aluminium Alloy Extrusions and Preformed Sheet Metal Sections, by W. Schroeder. (*Automotive and Aviation Ind., 15th January, 1944, Vol. 90, No. 2, p. 28*).

An account (with diagrams) of methods based on rolling, mechanical pressing with dies, stretch forming and combinations of these processes.

(*Communicated by the British Non-Ferrous Metals Research Association*).

The Pressing of Sheet Metal, Part I, by H. W. Swift. (*Sheet Metal Industries, June, 1944, Vol. 19, No. 206, p. 999, 5 figs.*).

A general survey. Theory and practice in presswork. Material. Tools. Presses. The hydraulic press. Feeding and discharge equipment. Cutting operations. Punch load. Rubber pad technique. Cupping and shallow drawing.

Small Steel Pressings, Parts I, II, by J. A. Grainger. (*Sheet Metal Industries, May and June, 1944, Vol. 19, Nos. 205, 206, pp. 837, 1043, 8 figs.*).

Tool design and tool setting. Limitations imposed by the metal. Roll feed work. Deep drawing. Single action, cushion-equipped presses. Rubber buffer cushioning. Hydraulic cushioning. Air cushioning. Technicalities of drawing. Design of drawing dies. Draw faces. Tool-setting for deep drawing.

Non-Ferrous Metal for Blanking Tools. (*Sheet Metal Industries, June, 1944, Vol. 19, No. 206, p. 1019, 23 figs.*).

The first description of British practice with particular reference to light alloy forming stock. Introduction. Simple type of blanking die devised to use zinc alloy has proved most satisfactory. Zinc alloys used. Properties of K.M. alloy. Procedure prior to tool design. Full-scale layout template procedure. Die design. Manufacturing the dies. General features of importance. General application. Summary.

Drawing Galvanised Wire: Methods Compared. (*Wire Ind., March, 1944, Vol. 11, No. 123, p. 133*).

Discusses the drawing properties of hot-dip and electro-galvanised wire, die dimensions, lubricants, etc.

(*Communicated by the British Non-Ferrous Metals Research Association*).

MANUFACTURING METHODS.

Process Control Terms, Proposed by Terminology Committee of Industrial Instruments and Regulators Division, A.S.M.E. [*Mechanical Engineering, (U.S.A.), March, 1944, Vol. 66, No. 3, p. 205*].

An attempt to compile a consistent and usable set of terms applying to industrial process control. A classified list of automatic control terms and definitions is given covering : (a) General automatic-control terms, (b) types of automatic controller action, (c) elements of automatic controllers, (d) terms related to controller adjustment, and (e) basic characteristics and elements.

The Napier Sabre Engine—II, III, by J. A. Oates. (*Aircraft Production, May, June, 1944, Vol. VI, Nos. 67, 68, pp. 230, 280, 58 figs.*).

Part II. Machining operations on the crankshaft, connecting rods, sleeve and sleeve ball. Machining sequence. Pin turning. Webb operations. Drilling the journals. Oil holes. Bolt seats. Grinding the web profile. Drilling the flange and countersinking. Connecting rods. Cap bolt holes. The sleeve. Sleeve ball. Sleeve worm housing. The impellor. Airscrew shaft cover. Pantograph milling and grinding. Gears.

Part III. Sub-assembly and final build. Balancing the impellor unit. Supercharger and engine testing. Gear backlash. Gear carrier liners. Balancing equipment. Outer cone assembly of impellor unit. Removal of metal from the clutch housing to correct balance. Lapping spherical seats in the airscrew shaft. Calibrating lubricant jets. Testing oil passages. Supercharger testing. First-build operations. Special assembly equipment. Engine test. Strip and final test.

Hawker Typhoon—II, III, by W. E. Goff. (*Aircraft Production, May, June, 1944, Vol. VI, Nos. 67, 68, pp. 212, 263, 72 figs.*).

Part II. Building the fuselage. Forward girder portion and rear monocoque. Girder fuselage. Monocoque fuselage. Fuselage frames. Quarter-monocoque assembly. Quarter section assembly. Assembly fixture. Hood rails and transport joint. Tail section. Tail section assembly. Fin assembly. Fin to tail portion.

Part III. Tailplane assembly. Main fixture. Rudder. Elevators. Fuselage decking. Radiator fairing. Under carriage-pivot casting. Cannon fairing.

The Production of the 0.50 inch Ammunition Link. (*Machinery, 11th May, 1944, Vol. 64, No. 1648, p. 505, 11 figs.*).

Link produced from strip steel on two Taylor & Challen presses. Special interest attaches to the second which performs four operations on the blanks, these being fed through it automatically. Now only two operators are required for the two presses with an output more than three times that formerly obtained with seven operators. Full description of multi-operation press, with general arrangement drawing of combination tools. Safety devices, and cut-out mechanism. Hardening and finishing links.

MATERIALS, MATERIAL TESTING.

Modern Metal Rolling Practice, by C. E. Davies and L. R. Underwood, (*Sheet Metal Industries, June, 1944, Vol. 19, No. 206, p. 986, 3 figs.*).

Theoretical and practical aspects of rolling mill operation. Effect of increase of rolling speed. Rolling load. Limiting factors for maximum draft. Elastic deformation of the rolls.

Freeze-treatment for Metals. (*Mechanical World, 26th May, 1944, Vol. 115, No. 2995, p. 571, 4 figs.*).

Controlling structural and dimensional change during manufacture. Practical uses. Refrigerating light alloy rivets and sheeting to delay ageing and preserve maximum workability. Refrigeration of tool steel. High speed steel improved from the point of view of hardness and ductility by freeze-treatment subsequent to and in conjunction with tempering. Refrigeration in the assembly line. The freeze-fit process with dry ice or liquid air. Examples. Apparatus.

Non-Destructive Testing. (*Automobile Engineer, May, 1944, Vol. XXXIV, No. 449, p. 181*).

M.A.P. abs. 121/5. from E.T.Z., Vol. 64, No. 31-32, New magnetic induction methods for non-ferrous, semi-finished metal products, e.g., tubes, rods or profiles, of nominally constant cross-section. Principles. Fault testing carried out simultaneously with inspections for dimensions and heat-treatment. Completely automatic test process. Rejects sorted for material on dimension faults. High speed of operation.

Further Experiments on the Damping Capacity of Metals and Alloys. (*N.E. Coast Inst. Engineers and Shipbuilders, Advance Copy, March, 1944*).

Factors affecting damping capacity. Variation in test conditions. Long-time testing. Variations in damping capacity of similar materials. Effect of air-resistance. Long periods of service. Number of impulses. Small changes of temperature. Degree of reproducibility from the same bar. Effect of variation of carbon content. Chromium content. Nickel content. Influence of defects in the material, and of additional sulphur content. Effect of cold-work. Effect of surface finish. Miscellaneous materials.

(*Communicated by " The Nickel Bulletin "*).

MEASURING METHODS, APPARATUS, INSPECTION.

Improvised Equipment for the Tool Room, by R. Harries. (*Machinery, 4th May, 1944, Vol. 64, No. 1647, p. 477, 13 figs.*).

Design of measuring equipment and methods of construction for : extending the range of a micrometer ; built-up sine bar ; radial setting arms useful in setting out hole locations in flat plate work, or spacing holes around a circle by the chordal method ; vernier height gauges from steel rules ; division plates ; and methods of taking long dimensions with high degrees of accuracy.

Optical Methods of Checking. (*Machine Shop Magazine, May, 1944, Vol. 5, No. 5, p. 39, 13 figs.*).

The Angle Dekkor. Description and principles of operation. Range of applications including the checking of : planeness of a baseplate, straightness of T-slots, parallelism of micrometer contact tips, angle of a taper sided piston ring. Taper diameters on an arbor, diameter of thread measuring cylinders, squareness of the faces of a thread rolling die block and squareness of table and tool head seatings on a vertical boring mill. (*Similar articles have appeared in : Machine Tool Review, March-April, 1944, p. 35 ; Automobile Engineer, May, 1944, p. 208 ; and Machinery, 1st June, 1944, p. 608*).

Servicing Employees' Micrometers. (*Production and Engineering Bulletin, February, 1944, Vol. 3, No. 15, p. 59, 3 figs.*).

J.P.C. suggestion for reducing avoidable scrap. Firm inspects and adjusts employees' micrometers for them free of charge. Fully 50% found to be inaccurate. Launching the scheme. How it works. Procedure for checking the micrometers.

Inspection without Gauges. (*The Machinist, 27th May, 1944, Vol. 88, No. 7, p. 38E, 5 figs.*).

Hilger projector. Workpiece projected against a template. Application to the checking of a sparking plug insulator. Advantages.

Three-Wire Measurement of Standard Whitworth and Fine Screw Threads, by J. F. Heaton. (*The Machinist, 3rd June, 1944, Vol. 88, No.8, p. 44E, 2 figs.*).

Tables of values for a range of threads are given which enable three-wire measurement to be made without calculation provided " best wires " (i.e., wires which will make contact with the sides of a thread at the pitch diameter) are used. The " best wire " size and the measurement over wires for various fits. Worked examples.

Some Principles of the Shewhart Methods of Quality Control, by W. Edwards Deming. [*Mechanical Engineering* (*U.S.A.*), *March, 1944, Vol. 66, No. 3, p. 173, 2 figs.*].

What the statistical method does. Inspection of critical items. Underlying principles—different kinds of variability. Problems and mistakes. How the control chart works. Specifications in terms of a distribution. Grounds for changing specifications. Responsibility of management. New uses. Conclusion. Literature.

Quality Control in Manufacture of Small-Arms Ammunition, by Hugh M. Smallwood. [*Mechanical Engineering* (*U.S.A.*), *March, 1944, Vol. 66, No. 3, p. 179, 8 figs.*].

The manufacture of small-arms ammunition and the institution of quality-control methods. Results obtained, illustrated by description of two operations where outstanding advantages have been obtained. Problems in gauge design. Reduction of rejects. Quality control of primer production. Conclusion.

X-RAYS, RADIOGRAPHY.

Weld Radiography, by E. V. Pullin. (*Mechanical World, 19th May, 1944, Vol. 115; No. 2944, p. 550*).

Important points regarding equipment, technique and interpretation.

The Control of Quality of Abrasive Wheels by X-Ray Inspection, by M. Terminasov and L. Kharson. Communication from The Röntgen Department of Mechanical Laboratory, Leningrad Institute of Railway Transport. (*Industrial Diamond Review, May, 1944, Vol. 4, No. 42, p. 96, 4 figs.*).)

Initial investigation with wheels of various materials using the fluoroscopic or visual method. Screen inspection of wheel bodies with a conveyor belt upon which the specimens can be fed into the X-Ray screening apparatus. Radiography necessary where wheel thicknesses exceed 2⅜ in. Data given applies to both green and fired bodies. (Detailed comments on the article, with X-ray photographs are given by E. J. Tunnicliffe, A.Inst.P.).

PLASTICS.

Injection Moulding—I, by J. L. Daniels. (*The Machinist, 13th May, 1944, Vol. 88, No. 5, p. 26E, 3 figs.*).

Extract from a paper, " Moulding Plant for Plastics," read before the Institution of Mechanical Engineers.

Injection moulding process for thermo-plastic materials. Simple injection moulding machine. Machines for hydraulic operation. Injection moulding of thermo-setting materials with direct injection method.

Plywood Moulding. (*Aircraft Production, June, 1944, Vol. 6, No. 68, p. 262, 1 fig.*).

The Thaden process which eliminates the pressure chamber, has recently been introduced in the United States. This uses air confined in a thin flexible bag restrained from expanding by the resistance of adjacent supporting surfaces, one of which consists of the die or mould on which the work is to be formed. Dies. Moulding procedure. Examples. Process for large panels.

Advances in Plastics During 1943, by G. M. Kline, [*Mechanical Engineering, (U.S.A.), April, 1944, Vol. 66, No. 4, p. 235, 1 fig.*].

New materials including replacements for natural mica. Cycleweld and Reanite cements, and resin-impregnated woods. Advances in moulding and fabricating techniques. Low-pressure laminating, postforming of laminates, and heatronic moulding. Survey of applications. Properties, testing and specifications. Books on the subject. Extensive bibliography (200 items).

Advances in Rubber During 1943, by J. W. Liska. [*Mechanical Engineering (U.S.A.), April, 1944, Vol. 66, No. 4, p. 241, 1 fig.*].

Production of synthetic rubber. A notable record of achievement. Chemurgic rubber substitutes. Nonchemurgic substitutes. Lining for concrete gasoline tanks. Testing properties of synthetics. Sources for substitutes. Crude rubber. Research. Extensive bibliography (133 items).

RESEARCH.

Some Psychological Factors Favouring Industrial Inventiveness, by Elliot Dunlap Smith. [*Mechanical Engineering (U.S.A.), March, 1944, Vol. 66, No. 3, p. 159, 1 fig.*].

Intuition and logic both essential. Applying intuition scientifically. Examples of Pasteur and Northrop. Faith an essential driving force. Intuition versus logic. Psychological requirements of inventiveness.

Research Workers for Industry, by A. P. M. Fleming. (*Aircraft Engineering, May, 1944, Vol. XVI, No. 183, p. 131*).

Education of research workers and their place in industry. Two broad types of research workers. The sequence of operations from initial discovery to commercial application. Examples. Time lag. Co-operation essential. Character of industrial research. Source of supply of research workers. Grants made by the Department of Scientific and Industrial Research to students training in different industries. Experience necessary for the industrial research worker. Importance of the teacher. Problem of small manufacturing concerns. Failure to utilize results. The research association. Comparisons with U.S.A. and the U.S.S.R. Our numbers of research workers far too small.

SHOP ADMINISTRATION AND MANAGEMENT.

The Foreman as a Part of Management, by H. B. Coen. [*Mechanical Engineering (U.S.A.), April, 1944, Vol. 66, No. 4, p. 249*].

Experience of more than 30 years in industry. Coming of the union. Change-over from peacetime to wartime. Number of foremen increased by war production demands. Problem of training. Foreman's role in management organisation. How to get better foremen ; selection ; training ; responsibilities ; contracts between the foreman and higher supervision ; support ; changes in policy. Personal creed.

The Control of Process Planning, by F. Cook. (*Machinery, 18th, May, 1944, Vol. 64, No. 1649, p. 545, 6 figs.*).

Definition and functions. Preliminaries. Sub-and final-assembly processing. Production schedule. Detail processing. Modification to processing for design or of manufacture considerations. Control of process sheets. Issue of production schedule.

Job Evaluation in Relation to Wage and Salary Structures, by Joan Maizels and Robert Watson. (*Industrial Welfare, May-June, 1944, Vol. XXVI, No. 294, p. 70, 5 figs.*).

Collective bargaining and the heterogeneous structure of national wage agreements. Job evaluation defined. The points system. Disadvantages in that it possesses a number of crudities and lacks comprehensiveness. The factor comparative method has been practiced, it is claimed, with good results in America since 1926. One method is to select for factor comparison, five factors, which cover all jobs. Each job is valued against these factors which are compared from job to job before a decision is made. The five factors most commonly used are the following although others may be added if thought necessary :—Intelligence requirements ; skill ; physical requirements ; responsibility ; working conditions. Organisation necessary to carry out this type of job analysis. Illustration of job analysis. Job analysis form. Ranking sheet. Complete ranking sheet with evolution of rates. A task for joint consultation. This article is followed by a comment from the trade union viewpoint.

SMALL TOOLS.

Negative-rake Milling. (*Machinery, 18th May, 1944, Vol. 64, No. 1649, p. 533, 12 figs.*).

Negative rake gives a stronger cutting edge—one that will enable the cemented-carbide tips to withstand better the severe shocks that occur in taking interrupted cuts on steel.

However, considerably more power is required to drive negative-rake cutters, so much more that present-day machine tools are under-powered for this practice. A negative rake of 10 deg. and a negative helix angle of 10 deg. have in the experience of several concerns proved satisfactory for the machining of both hardened and normalized or annealed steel, although there are works that vary these angles somewhat, depending upon the analysis of the material being cut. Negative rake cutters are being applied both on the climb-cut principle and in the conventional manner. The shock of the impact on each tooth as it engages the work is taken a perceptible amount behind the cutting edge at a point where the tooth is thicker and stronger. In addition to the high cutting speeds and feeds that can be employed with these milling cutters, a finished surface of exceptional smoothness and high polish is produced on the work, comparable only to a ground or burnished finish. Opinions as to the reasons for this high finish are as yet largely a matter of conjecture because there has been little scientific investigation of this subject. Coolant is not used with negative-rake milling cutters. Test and actual practice have shown that the bite of feed per tooth should seldom be less than 0.003 in. With a feed per tooth of less than 0.003 in., the impact shock as the tooth enters the workpiece is at the very edge of the tooth, which is its weakest point. This practice would shorten the life of the cutter between grinds. In one test, the cutter life between grinds was increased by 200% by simply raising the feed per cutter from 0.005 to 0.010 in. The table feed was doubled and the cutting speed left unchanged. Experiments seem to indicate that when machine tools of greater power and rigidity are available, even more spectacular

performances may be possible with negative-rake cutters than those now being achieved in regular production. The production of chips is so fast that provision must be made for rapid removal of chips. Without these provisions, chips would often be recut as they adhered to the cutter, a condition tending to produce tip fracture and breakage.

Applications of Negative-Rake Milling. (*Machinery, 25th May, 1944, Vol. 64, No. 1650, p. 561, 6 figs.*).

The concentricity of the cutter and the accuracy of the cutting plane have a direct bearing on the number of parts per grind. For example, if any one tooth on a face-mill should extend 0.001 in. higher than the others, that tooth would take a heavier chip load, and paradoxical as it may seem, that tooth would hold up longer than the teeth that are taking lighter chip loads. Evidence is shown that a feed per tooth of less than 0.003 in. causes excessive wear, regardless of the material being machined. In order to eliminate vibration, the cutter bodies are made of some such shock-absorbing material as Meehanite, and flywheels are mounted on the cutter-arbor whenever the set permits. These flywheels are made up in 80 lb. weights, and as many as three flywheels are mounted on one arbor. The flywheels, of course, also make it possible for cuts to be taken that would otherwise necessitate motors of greater power. It has been found that the greater the negative rake; the greater the horsepower requirements. Changes in the helix angle do not affect horsepower requirements appreciably. Single fly cutters of negative rake are used to some extent for milling steel parts. Negative rake carbide-tipped fly cutters are used extensively for machining aluminium castings and bar stock.

Cemented-Carbide-Tipped Milling Cutters, by F. W. Lucht. [*Mechanical Engineering (U.S.A.), March, 1944, Vol. 66, No. 3, p. 192, 8 figs.*].

Reasons for the long delay in the successful application of cemented carbides to the milling of steel. Importance of rigidity of setup, power, the proper cutting speed, the proper tooth loading, and the proper combination of positive and negative cutting angles. Same basic principles as applied to single-point tools which take interrupted cuts. Discussion of these principles in lathe work and their extension to milling practice. Design considerations. Axial rake angle (negative). Radial rake angle. Bevel angle. Chamfer or radius. Fly-cutting tools. Multitooth cutters. Face. Tip thickness. Grade of cemented carbide. Speed and feed. Number of teeth and power. Design of cutter body. Diameter of cutter. Fly cutting. Rigidity in the machine and fixture for holding work. Operating precautions. Dragging work across cutter on return stroke. Cutting dry versus cutting wet. Chip removal. Climb milling versus conventional milling. Face milling versus plain milling. Cutter grinding.

Tools for High-Speed Milling—and for Shell Forging, by N. G. Meagley, (*Met. Progress, January, 1944, Vol. 45, No. 1, p. 91*).

A survey of papers read at the 64th Annual Meeting of the American Society of Mechanical Engineers, 1943.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Chip Control with Sintered-Carbide-Tipped Tools, by M. F. Judkins. [*Mechanical Engineering (U.S.A.), March, 1944, Vol. 66, No. 3, p. 201*].

Chip control of great moment in the machining of steels and other dense or highly alloyed, tough, ductile metals. Factors in chip formation. Methods of controlling chips. Ground-in chip groove. Procedure for grinding grooves.

Chevrolet Develops Low-Cost Cutters for Finning P. and W. Pistons. (*The, Machinist, 3rd June, 1944, Vol. 88, No. 8, p. 83*).

Cutter cost has been reduced 75% by evolution of a two-blade cutter, for which the body is blanked from SAE 1020 steel and the cutting edges are produced by depositing tungsten carbide into the tooth recesses by gas welding. Details of cutter manufacture, including cost. Difficulties in use overcome.

Fundamental Design of Hand Tools for the Disabled Man—I, II, by Dr. G. Schlesinger. (*The Machinist, 29th April, 6th May, 1944, Vol. 88, Nos. 3, 4, pp. 14E, 20E, 9 figs.*).

This article is based on experience with about 15,000 hand-mutilated soldiers in World War I, more than 90% of whom regained fully-paid positions in their former trades. Hand features. Universal adaptability. Shoulder, elbow and wrist joints and their mechanical replacement. Selection from the almost infinite possibilities of the human hand of the most important and frequently repeated operations for the artificial limb. Selection of tools for the artificial hand. The artificial modelled hand to hold a pencil, pen or any similar article. Use of the remaining healthy hand to adjust the artificial holder. Design of clamping screws. The big joints. Well-proved short-wrist joint and a long elbow joint. Use of 1 lb. to 1½ lb. hammers. Clutched arm. Bandage connecting the artificial sleeve to the stump of the arm. Heavy work. Arrangement for weight to be carried by shoulder and back. Filing. Training the man.

Truing and Dressing Grinding Wheels with Diamond Tools. (*Industrial Diamond Review, May, 1944, Vol. 4, No. 42, p. 109, 4 figs.*).

A review of some recent international patents including : arrangements relating to the truing of stepped grinding wheel profiles. Truing device to enable wheels to be trued with faces at right angles to the wheel axis ; and gear grinding truing device.

The Relation between Weldability and Wear of Cutting Tools, by W. Dawihl and W. Rix. (*Metallurgia, March, 1944, Vol. 29, No. 173, p. 270*).

Translation of a German paper published in Z. Metallkunde, July, 1942, 34/7, 156-159 (B.N.F. Serial 25,562) and noted in B.N.F. Bulletin 164, February, 1943, p. 58.

(*Communicated by the British Non-Ferrous Metals Research Association*).

SURFACE, SURFACE TREATMENT.

Practical Standards for Surface Finish, by Dr. Geo. Schlesinger. (*Machinery 4th May, 1944, Vol. 64, No. 1647, p. 492*).

Comment on a note by Mr. J. D. Scaife, calling for a tolerance chart for surface finish. Measurements of surface finish as obtained by various British industries. "Good enough" should be the watchword of production both for the surface finish and the dimensions of a part. Comparison of surface finish of piston skirts from first-class British and German aero-engines. Vibrogram of the main spindle of a diamond turning lathe. British and American standardized steps for surface quality. Distribution of 460 typical surfaces both according to machining operations used and to the proposed 12 steps. Comparison of surface-finish on British and American motor car parts. Surface qualities proposed for the most-used machining operations.

Surface Finish. (*Aircraft Production, June, 1944, Vol. 6, No. 68, p. 301, 1 fig.*).

Scheme, which the General Electric Co. of America has used for the past ten years, describing finishes with the aid of actual specimens. Characteristics on which performance of a machined surface depends. Instruments. Performance results. Symbol used. 10 degrees of roughness. Sample finishes, used by design engineers, draughtsmen, shop mechanics, and inspectors. Comparison with samples in inspection. Table of relative costs of different finishing processes.

Metal Colouring : Decorative and Light-Duty Finishes, Part V, by H. Silman. (*Sheet Metal Industries, May, 1944, Vol. 19, No. 205, p. 841, 7 figs.*).

Phosphatised zinc coatings. Use of titanium pre-dip. Flexible coatings. Plant required. Colouring of steel. "Oxidised" finishes. Miscellaneous methods for steel. Colouring copper and its alloys. Thioantimoniate solutions and other methods. Cadmium colouring. Colouring zinc by "Cranak" and other processes. Colouring aluminium. Gilding.

Electrolytic Methods of Polishing Metals, by S. Wernick. (*Sheet Metal Industries, June, 1944, Vol. 19, No. 206, p. 979, 8 figs.*).

Part II—Electrolytic polishing of stainless steels. Phosphoric acid process. Degree of polish as affected by the basis metal. Sulphuric acid process. Comparison. Auxiliary mechanical polishing. Influence of shape, etc. Practical difficulties.

WELDING.

Flash Butt Welding for Tool Tips. [*AEG, Z.V.D.I., Vol. 88, No. 7/8, 19th February, 1944, p. 27, (adv. section)*].

In order to conserve materials, it has been common practice to use composite tools, in which a plate of high speed steel destined for the cutting edge is attached to a holder made of cheap structural steel. The attachment is usually carried out by brazing or fusion welding with the addition of filings and borax. The employment of flash butt welding for this process presents many advantages and the special tool holder developed by the AEG for this purpose and used in conjunction with a standard flash butt welding machine is illustrated. The tool clamp proper consists of an upper and lower jaw made of steel whilst the plate clamp for the high speed tool tip is made of copper in order to equalise the electrical resistances. The strength of the flash weld is very great and the weld zone can be even subsequently forged if necessary. The heat zone is very limited and there is no danger of the high speed plate being burnt. It is even possible to use plates already hardened so that the tool only requires grinding before being ready for use. The use of unhardened materials is, however, generally recommended, as this facilitates grinding, and at the same time enables the weld to be subjected to a proper test. For subsequent hardening, the temperature most favourable for the high speed plate can be chosen without any danger of the weld cracking.

(*Communicated by the Ministry of Aircraft Production*).

Arc Welding Low Alloy High Tensile Structural Steel, by J. G. Ball, (*Welding, May, 1944, Vol. XII, No. 6, p. 223, 14 figs.*).

Influence on metallurgical properties. Reeve fillet weld cracking test. Modifications by Dearden and O'Neill. Interpretation of tests. Fillet sizes. Effect of plate thickness. Effect of preheating. Effect of type of joint. Recommendations for welding. Coefficients for calculating carbon equivalents. Electrodes.

Automatic Arc Welding as an aid to Increased Production, by R. F. Wyer. (*Sheet Metal Industries, June, 1944, Vol. 19, No. 206, p. 1055, 12 figs.*).

Applications involving metal arc and atomic-hydrogen arc welding. Main factors. Electronically controlled automatic arc welding head. Automatic arc voltage control. Automatic atomic-hydrogen arc welding heads. Automatic atomic-hydrogen welding technique. Production requirements for automatic arc welding. Dual machine operation with one operator.

WORKS AND PLANT.

Chip-Disposal Methods, by Frank J. Oliver. [*Mechanical Engineering, (U.S.A.), March, 1944, Vol. 66, No. 3, p. 163, 12 figs.*].

Segregating scrap and orderly salvage methods. Economic factors. Marking systems. Examples of handling, crushing, centrifuging, and briquetting practice for various materials.

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